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ALEXANDRIA VA S L CHANNON APR 85 IDA-M-81

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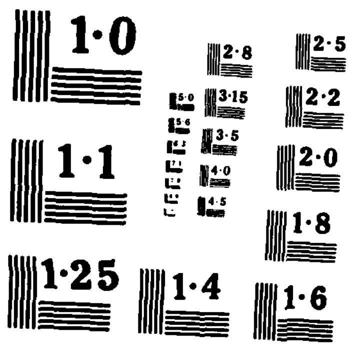

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IDA MEMORANDUM REPORT M-81

MINUTES OF WORKSHOP ON COMPOSITE MATERIALS TEST METHODS

Held at Institute for Defense Analyses
February 27, 1985

Stanley L. Channon, *Editor*

April 1985

Prepared for
Office of the Under Secretary of Defense for Research and Engineering

IDA

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, VA 22311

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The advanced composite materials community has recognized the need for standardization of test methods as the most important step in improving the acceptance of composite materials, in providing a reliable data base and in qualifying new materials. A survey of advanced composites suppliers and end users showed a strong interest in developing standardized test methods, the greatest need being for shear and compression testing as well as standardized methods for test specimen preparation. A test program was formulated which

20. Abstract (continued)

is aimed at screening available methods in these areas on several types of materials, determining the repeatability of selected test methods by testing at a large number of laboratories, followed by analyses of the data. In addition, provision is made for the development of improved test methods and subsequent evaluation of these methods. The first phase of the program was estimated to cost $2.5 million and would require 2.5 years for completion.

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Task T-2-119

PREFACE

This document is a record of the minutes of a workshop held on February 27, 1985 for the purpose of formulating a program plan for the development of improved standardization in methods for testing composite materials. The workshop was prompted by an industry-wide concern over the lack of standardization and interchangeability of test data and qualification criteria for advanced composite materials, as expressed in a previous workshop on May 8-10, 1984.

These minutes form the basis for recommendations on required funding to accelerate the development of test method standardization. The proposed program is intended to provide experimental data needed to develop a sound basis for ASTM standards for some selected test methods (initially shear and compression).

Since this document is merely a record of the workshop proceedings and recommendations, it has not been formally reviewed.

TABLE OF CONTENTS

MINUTES OF WORKSHOP
ON
COMPOSITE MATERIALS
TEST METHODS

A. INTRODUCTION

At the DoD-sponsored colloquium on Composite Materials and Structures - Standardization, Qualification and Certification held on May 8-10, 1984 (Ref.1), the conferees identified test methods for composite materials as one of the highest priority items needed in the standardization and qualification of composite materials. All working groups at this conference independently concluded that the establishment of standard test methods and the development of improved test methods to replace those existing methods considered to be inadequate was an essential prerequisite to the generation of a reliable data base for the qualification and design of composite materials.

In addition to improving the acceptability of composite materials in structural applications, the establishment of test method standards was expected to result in economic benefits through a reduction in the amount of testing needed to qualify materials and establish design data. Other aspects of standardization (such as material nomenclature, specifications and material characterization) were also addressed in the aforementioned meeting but they were not included in this workshop.

As a first step in addressing test methods in more detail, a questionnaire (Appendix 1) was prepared jointly by IDA and ASTM and was sent to all attendees at the Colloquium and also to several other interested organizations to determine the prioritized interest in certain tests and opinions on other aspects of ASTM and government involvement in test methods.

Since the results of this survey were strongly positive, a workshop was arranged to formulate a general plan for a coordinated national effort to develop standardized test methods for composite materials. The focus of the workshop was on initial selection of methods to be studied, materials of interest, potential participants, scope of testing needed, organization and management, estimated cost and schedule.

The workshop was held at the Institute for Defense Analyses, 1801 N. Beauregard St., Alexandria, VA., 22311 on Wednesday, February 27, 1985 with 32 attendees from Government, industry, university and non-profit organizations. (See Appendix 2 for list of attendees). The workshop agenda is included as Appendix 3.

B. PRESENTATIONS

Short presentations were made by several participants in order to provide all attendees with brief descriptions of activities related to the subject. Copies of these presentations are included as Appendices with brief editorial summaries provided in the following paragraphs.

1. Review of IDA/ASTM Survey on Testing Needs,- S. L. Channon. (Appendix 4)

A report describing the results of this survey was provided to each attendee at the start of the workshop. The survey showed that the greatest need was for standardization of tests for compression and shear (in-plane and interlaminar), specimen preparation methods, non-destructive testing methods, methods for testing toughened resin composites and chemical characterization.

Other questions covered the following topics and all received overwhelming positive responses.

a. Interest in Assisting in Test Development.
b. Need for DoD/NASA Support.
c. ASTM Role in Non-Destructive Testing.
d. ASTM Role in Chemical Characterization.
e. ASTM Role in Practices for Specimen Preparation.
f. Need for Certified Test Laboratories.
g. Use of Certified Test Laboratories, if Established.
h. ASTM Role in Establishing Criteria for Certifying Laboratories.
i. Other Areas for ASTM Attention.

Details of the responses, together with individual responses are included in Appendix 4.

2. ASTM Committee D-30 Activities - W. W. Stinchcomb. (Appendix 5)

The scope of ASTM Committee D-30 on High Modulus Fibers and Their Composites was reviewed and the liaison activities with the MIL Handbook 17 Committee, JANNAF Rocket Motor Case Committee, Army Committee on Test Methods for Polymeric Composites (MIL-STD 1944) were pointed out.

The survey results supported ASTM's assessment of the need for test methods. Compression testing has been expanded to include consideration of these test methods; several shear testing methods are included as standards but none is suitable;

modification of flexure testing is being reviewed. Round-robin testing and symposia are being arranged on the subjects of delamination and debonding, and on metal matrix composites testing.

Problem areas related to the development of standard tests for composite materials were reviewed. In particular, boot-legging of test method development is often necessary in order to make any progress in improving test methods. Non-use or mis-use of ASTM standards was mentioned as a problem in assessing data on materials testing.

Possible mechanisms for supporting an expanded program through ASTM were discussed. Precedence for such support has been established through grants and contracts from NRC and DOE.

3. MIL Handbook 17 Activity. - P. Doyle. (Appendix 6)

The current activities relating to the generation of MIL Handbook 17 for selected advanced composite materials were described and some of the problems revewed. The program had no guidelines initially, so it became necessary to develop a set of guidelines. Shear and compression testing are being emphasized. Methods of statistical analysis of the data are being reviewed. The need for feedback on the data was emphasized. It was estimated that the time cycle to develop the data base for a material is about 2 years. By late 1985 or early 1986, it is expected that data will be available on the carbon fiber/epoxy resin systems (AS4/3501-6 and T-300/934) being tested at present. A section on Kevlar has been prepared.

4. MIL Standard 1944 - F. Traceski (Appendix 7)

It was pointed out that the Defense Standardization and Specifications Program (DSSP) is an all-encompassing program covering specifications, standards, handbooks and related activities. A number of documents covering the DSSP program were referenced; in particular, it was pointed out that Publication SD-9 on Non-Government Standards Bodies should be applicable to ASTM activities. MIL Std. G-46187 covering polymid and bismaleimide is part of the AMMRC responsibility in standardization of composites. It was also mentioned that the Government is funding AMS to develop specifications.

It was felt that standardization was well in hand and no further efforts are needed.

5. NASA/Industry Specification Program - J. Davis (Appendix 8)

The cooperative program between the three major commercial aircraft companies (Boeing, Lockheed and McDonnell-Douglas) under NASA management for the purpose of developing a common specification for procurement of composite prepreg was described.

It was pointed out that NASA does not usually support specification development unless it is a major user.

The material was specified in terms of carbon fibers exhibiting 1.5 percent minimum strain to failure in a toughened thermoset polymer matrix. Test panel fabrication was also specified in terms of a 350.F max. cure at a pressure of 100 psi max. Test methods selected for the program matched those shown in the survey (Appendix 4). NDE was used to characterize the panels; void content of 2% maximum was specified for the test panels.

The publication of this specification is expected in March, 1985.

6. High Temperature Composites Testing and Standards - P. DiGiovanni. (Appendix 9)

The problem of inconsistency in testing and resulting property data was illustrated by reference to a recent workshop following the American Ceramics Society meeting in January, 1985, at which two major airframe manufacturers reported widely different "A" allowables in tension for the same material (one reported more than 200,000 psi and the other reported 153-155,000 psi).

A number of problems relating to testing composites (due to their anisotropy) were reviewed and actions to improve the situation were recommended. Special mention was made of the need for improved high temperature testing, especially for discontinuously reinforced metal matrix composites. A round-robin program on this class of material was recommended as a means of developing a learning experience on test methods development.

It was also pointed out that test fixtures and procedures must be compatible with industry needs and accuracy requirements. Data analyses, presentation and documentation should also be addressed so that complete descriptions of test methods are reported rather than general references.

7. JANNAF Motor Case Test Methods - A. Munjal (Appendix 10)

The current survey of test methods used by various organizations associated with motor case manufacture and acceptance was reviewed. The sub-committee on Testing and Inspection is collecting information on the use of these methods throughout the industry. Test method development is not a major objective of the sub-committee effort, however.

It was stated that anisotropic materials such as composites often require as many as 21 tests to characterize the material whereas isotropic materials may be characterized with as few as 2 tests. Processing standardization is also essential in composites.

The JANNAF group will be addressing non-destructive inspection at the Tri-Service meeting in Monterey on March 4, 1985.

A paper by A. Munjal on "Test Methods for Characterization of Fiber Reinforced Composites" was also provided to all attendees (Appendix 11). This paper reviewed the status of test methods, with comments on the advantages and disadvantages of each method. Recommendations on methods suitable for design allowables and for quality control testing are provided.

C. WORKSHOP GOALS.

Following the individual presentations, the following subjects were addressed in the workshop:

Selection of Test Methods/Materials
Scope of Testing Program
Cost Estimates and Funding Sources
Organization and Participation
Management and Documentation
Schedule

The results of the discussions in each of these areas are summarized in the following sections.

1. SELECTION OF TEST METHODS AND MATERIALS.

a. Test Methods.

The survey showed the relative need for standardization of the test methods included in the survey. The attendees elected to concentrate on the top six items on that list, namely compression, shear, specimen preparation, NDT, toughened resins and chemical characterization. Following the discussions of each of these items, it was concluded that initial emphasis should be placed on shear and compression testing and specimen preparation methods.

Reasons for not including the other three items were as follows. While NDT was considered to be a useful method of evaluating the general quality of specimens and hardware, and should be included as part of the test program for that purpose, special emphasis was needed on non-destructive testing and correlation with material properties which is beyond the scope of the program under consideration.

Toughened resin testing is being addressed by ASTM in a special symposium on this subject in March, 1985. Also, toughened resins were considered to be more aligned with a material option rather than a test method, per se. While recognized as an area of importance, the workshop participants voted to exclude this item from the present program.

Chemical characterization methods, although ranking high on the priority list, were believed to be sufficiently well established that they could be used, although they have not been universally accepted yet. Chemical characterization should be used to characterize the test specimens used in the test progam but it was felt that further methods development could be deferred at this time.

Specimen preparation methods were emphasized as being a necessary prerequisite for any test method. This should probably be addressed in detail prior to or in conjunction with the compression and shear testing method development.

It was pointed out that test methods may be different for different requirements such as qualification, acceptance or design data. Somebody needs to be in charge of establishing these requirements. It was also mentioned that characterization tests are often run on unidirectional test coupons rather than on laminates. Cross-ply specimens must also be considered.

b. Materials.

The attendees reviewed the various classes of materials and recommended inclusion of the following fiber reinforcements and matrix materials:

Reinforcements	Matrix
Carbon, High Strength	Epoxy - Standard (Brittle)
Carbon, High Modulus	Epoxy - Toughened
Carbon, Ultra High Modulus	Bismaleimide
Aramid (Kevlar)	Polyimide
Glass (S-2)	Thermoplastic
Silicon Carbide (discontinuous)	Metal

Not all materials will be carried through a test development program. A review of existing information may be needed to make selections of the most appropriate materials.

Carbon-carbon and ceramic matrix composites were consciously omitted from consideratiion in this program. Carbon-carbon testing has been the subject of special attention for a number of years and was felt to be adequately covered. Ceramic matrix composites are not sufficiently developed yet.

It was suggested that the test matrix of methods and materials be considered in two phases, the first phase being devoted to narrowing the number of test methods in each type of test to a select few and the second phase including a wider selection of materials to determine the applicability of the methods to different classes of material, as well as verifying the methods at several laboratories.

It was concluded that about 5 combinations of fiber and matrix from the above materials should be included in the test development program for planning purposes. One of these may be a discontinuously reinforced metal matrix composite.

2. SCOPE OF TEST PROGRAM

The overall plan for a test development program should include the following items:

- Test Plan
- Material Acquisition
- Material Inspection
- Coupon Preparation
- Coupon Instrumentation
- Coupon Testing
- Data Acquisition
- Data Analysis
- Documentation

Several iterations were discussed before arriving at a general plan which would encompass a reasonable but statistically acceptable number of tests.

It was concluded that a two-phase program for each major test method would be preferrable, as follows:

Phase 1 - This phase is primarily a screening phase. For each major test method (e.g. shear), it was assumed that 5 individual methods would be selected for comparison. Two test conditions (e.g. room temperature and elevated temperature) and 10 test coupons per condition would be required. Round robin tests would be conducted at three laboratories.

This results in 300 test coupons per material per test method.

Phase 2 - This phase provides more statistically significant data on a selected method. The assumption is made that 10 laboratories will be involved in testing 20 coupons for each of 3 variables (methods and/or materials) selected from Phase 1. This phase will require 600 tests.

For the assumed program described above, 900 specimens would be needed for each test method and material type. Assuming 3 test methods (shear, compression and specimen preparation) and 5 materials (selected from the above list), the total number of test coupons amounts to 13,500.

Although not specifically spelled out in the methods variables mentioned, it is anticipated that some test method modifications may be incorporated in the program, especially in those cases in which a method is not considered to be satisfactory and can be improved. Thus, the methods to be evaluated may include new or modified methods as well as existing methods. The selection of the methods variables will require considerable study and consultation with testing experts.

3. COST ESTIMATE

The workshop attendees recommended that a cost of $125 per test specimen be used as an average cost which includes labor and overhead for specimen preparation testing and data reduction. Material costs were not separately estimated.

Based on 13,500 test coupons, the testing cost is estimated to be $1,687,500. Data analyses and fixtures needed for modified test methods are estimated to be approximately $300,000. Other items such as review of existing methods, meetings, travel, etc. may add $200,000. The total estimated cost for the program outlined is $2,200,000. For budget purposes, it is recommended that a total of $2,500,000 be assumed.

4. ORGANIZATION AND PARTICIPATION

Based on the results of the survey, it was evident that a large number of organizations is interested in participating in a program of test method development. Voluntary participation was discussed but problems were expected in coordinating and managing the program.

Because of the large number of organizations expected to be involved in the program, it appeared that a central point of control would be essential. Thus, a general contractor with numerous sub-contractors appeared to be needed. Discussion on the organization therefore centered around the management of the program.

5. MANAGEMENT AND DOCUMENTATION

Several potential management approaches and organizations were suggested, as follows:

a. ASTM.

As the recognized organization for the establishment of test methods, was considered to be a natural contender. Some precedent has been established for this kind of management effort. However, there were concerns that the scope and administrative details of this program are larger than ASTM could handle in its normal mode of operation. Some felt that the ASTM role (through ASTM Committee D-30) should be advisory rather than administrative. The results of the program will be submitted to ASTM for possible incorporation into ASTM standards. ASTM would then assume its usual role in polling its members for consensus approval of the proposed standards.

b. Private Industry or Laboratory.

Several attendees favored the idea of contracting the management of the program to some private organization with a Steering Committee or advisory committee to review the program at key stages. The Steering Committee may include ASTM, industry and government members.

The private industry manager would be responsible for the detailed planning and administration of the program according to the general directions of the Steering Committee. The program manager would also be responsible for all subcontractor arrangements, coordination of all elements of the program, preparation of a report and periodic program review briefings.

c. Other Organizations

Several other potential manager organizations were suggested. These included the Defense Standards and Specifications Organization (through AMMRC), JANNAF, Universities, Commercial Test Laboratories and the newly-formed Suppliers of Advanced Composite Materials Association (SACMA).

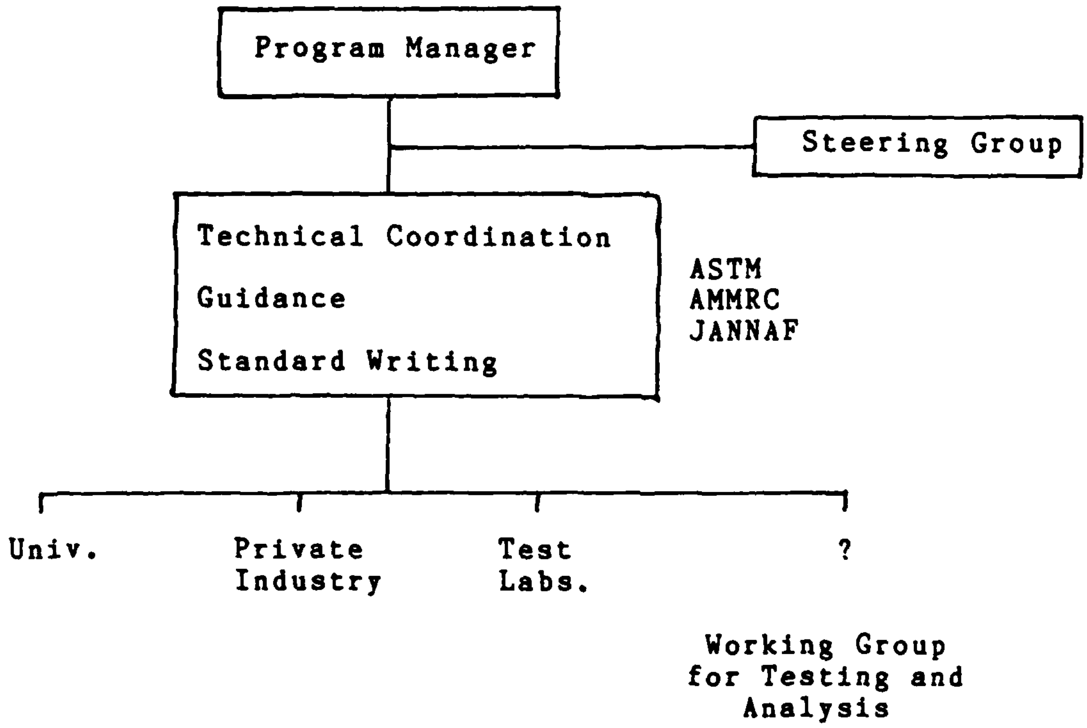
DSSO was perceived to be an organization whose responsibilities include a very broad range of standards and specifications for DoD but is not staffed to manage a program of this type. AMMRC is currently engaged in establishing data for MIL-Handbook 17 through a controlled test program using in-house laboratory facilities. AMMRC could be considered as a possible program administrator.

The JANNAF Committee, Universities and Test Laboratories were not discussed in detail. JANNAF Committee members would probably serve in an advisory role whereas universities and test laboratories may be active participants or, in some cases, serve on an advisory committee.

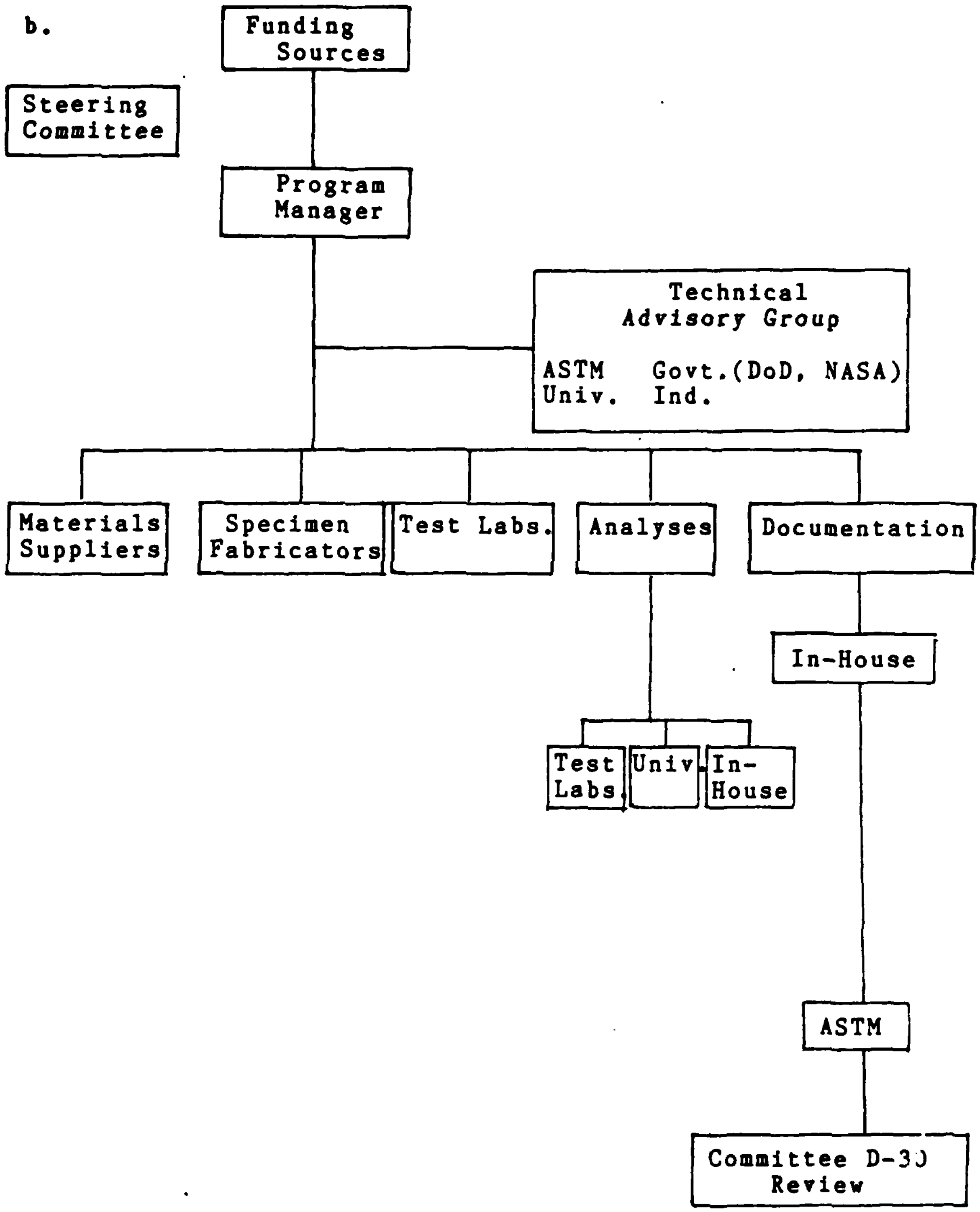
SACMA has yet to form its committees and define their goals. This organization is not viewed as a potential program manager but may wish to participate by providing a communication link with suppliers and perhaps providing representation on a steering committee.

There was some discussion on the relationship between the program manager, steering committee, currently active groups such as ASTM, AMMRC, JANNAF and participants such as test laboratories. Detailed working groups and their functions were not addressed. The following alternatives were presented for future consideration.

a.


Program Manager
Steering Group
Technical Coordination
Guidance
Standard Writing
ASTM
AMMRC
JANNAF
Univ.
Private Industry
Test Labs.
?
Working Group for Testing and Analysis

b.


Funding Sources
Steering Committee
Program Manager
Technical Advisory Group
ASTM Govt.(DoD, NASA)
Univ. Ind.
Materials Suppliers
Specimen Fabricators
Test Labs.
Analyses
Documentation
In-House
Test Labs.
Univ.
In-House
ASTM
Committee D-30 Review

6. SCHEDULE

The workshop participants estimated that the general program outlined above could be completely in a period of 2 - 2.5 years. This would provide a technical report with recommended standards for adoption.

ASTM pointed out that there was no guarantee that ASTM standards would result from this program. This would depend on the acceptance of the proposed standards by ASTM Committee D-30 through the normal procedure for adoption of standards. This process could take considerable time. However, the amount and quality of the data furnished to ASTM should be significantly higher than normal so it is expected that the approval process could be shortened.

7. SUMMARY

As a result of this workshop, the following program was outlined to develop test methods for the most needed properties for composite materials.

1. Test Methods or Standards
   - Shear
   - Compression
   - Specimen Preparation

2. Test Plan - 13,500 specimens
   - Phase 1 - Screening
     - 5 methods each in shear, compression, specimen preparation
     - 2 test conditions
     - 10 coupons per condition
   - Phase 11 - Method Evaluation & Verification
     - 3 variables (methods or materials)
     - 10 laboratories
     - 20 coupons per variable

3. Organization & Management.

   Options include single manager or committee. Preference is toward a single manager, perhaps in private industry. A Steering Committee should be organized to advise program manager. Participation by materials suppliers, fabricators, and test laboratories will be necessary.

4. Cost & Schedule

Total cost estimate	$2,200,000 - $2,500,000
Schedule	2 - 2.5 years

8. RECOMMENDATIONS

The workshop was successful in providing a general plan and suggestions for organization and management options. The next step is to study the detailed organizational structure, funding sources and possible program management arrangements.

A smaller committee should be convened for the purpose of exploring funding sources and defining an organizational document and methods of operation.

Arrangements for the next meeting will be made after the SAMPE meeting and the SACMA meeting on March 19-21 and March 22 respectively.

REFERENCES

1. Proceedings of Colloquium/Workshop on Composite Materials & Structures, Standardization, Qualification, Certification, Stanley L. Channon, IDA Record Document D-70, July 1984.

APPENDIX 1

QUESTIONNAIRE

APPENDIX 1

QUESTIONNAIRE

Composite Materials
Test Methods Development and Standardization

The recommendations and suggestions resulting from the IDA Colloquium/Workshop on Composite Materials and Structure: Standardization, Qualification, and Certification identify several needs which can be filled by voluntary action by industry and government in cooperation with ASTM. Your answers to the following questions expressing the anonymous position of your organization, will help determine the directions to be taken to implement some of the recommendations and suggestions. Please review the IDA report before answering the questions.

1. The following tests have been identified as being either inadequate, non-existent or insufficiently standardized. Please indicate the order of priority which you feel should be assigned to the development of these tests. Add any additional tests to this list which are in need of development or standardization.

____ Shear

____ Compression

____ Toughened resin matrix (including adhesives)

____ Coefficient of Thermal Expansion (esp. for metal matrix composites)

____ Tests Applicable to More Ductile Fibers

____ Flexure Test for High Performance Composites

____ Non Destructive Test Methods

____ Chemical Characterization (HPLC, etc.)

____ Test Specimen Preparation

____ Bolt Bearing Tests

____ Ply Count in Laminate

____ Fiber Content in Composites with Polymeric Fibers

____ Moisture Content

____

____

____

____

2. Would your organization be interested in assisting in the development of any of these test methods (no commitment required at present)?

Yes _____ No _____

If so, which ones? ______________________________

____

____

3. Should DOD and or NASA be asked to support the development of these methods? (If yes, how should development be supported?)

Yes _____ No _____

Comments:

4. Should ASTM play a more active role in developing non-destructive testing methods for composites?

Yes _____ No _____

Comments:

5. Should ASTM be involved in developing methods to chemically characterize matrix materials?

Yes _____ No _____

Comments:

6. Should ASTM develop a recommended practice for test specimen preparation?

Yes _____ No _____

Comments:

7. Is there a need for having testing laboratories certified for testing composites?

Yes _____ No _____

Comments:

8. Would you use independent certified laboratories?

Yes ______ No ______

Comments:

9. Should ASTM, with the cooperation of industry and government, set up the criteria for certifying composite materials testing laboratories?

Yes ______ No ______

Comments:

10. What other or new areas of composite material technology should ASTM be addressing?

Please return the questionnaire by 31 January 1985 to:

Dr. Stanley L. Channon
2361 Daventry Road
Riverside, CA. 92506

APPENDIX 2

INVITATION AND ATTENDEES AT WORKSHOP

IDA

SCIENCE AND TECHNOLOGY DIVISION

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311 • Telephone (703) 845-2000

As a participant in the DoD/IDA Colloquium on composite materials in 1984, and as a respondent to the recent questionnaire on test methods, you are cordially invited to attend a one-day workshop on TEST METHODS FOR COMPOSITE MATERIALS - DEVELOPMENT AND STANDARDIZATION to be held at the Institute for Defense Analyses, 1801 N. Beauregard St., Alexandria, VA. 22311 on Wednesday, February 27, 1985 from 9:00 am to 5:00 pm.

The purpose of this workshop is to formulate plans and recommendations for a coordinated national effort on test method development and standardization of tests for composite materials. As an introduction, a presentation will be made of the results of the questionnaire sent out to industry and government organizations with the Proceedings of the 1984 Colloquium. Current programs on test method development by ASTM, AMMRC and others will also be summarized.

The survey showed an overwhelming interest in improving test methods standardization as the first step in establishing a reliable data base for composites. With this need established, the workshop will focus its attention on methods for accomplishing the above goals, including industry, university and government participation, funding and organization, as well as some of the details relating to the selection of test methods, materials, test laboratories and round-robin testing. Schedules for accomplishing these tasks will also be addressed.

It is anticipated that this workshop will also result in the formation of a task force or steering group which will provide overall guidance to such a national program through periodic meetings.

Your continued support is earnestly solicited.

Sincerely yours,

Stanley L. Channon

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Consultant to IDA
714-683-7357

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COMPOSITE MATERIALS TEST METHODS DEVELOPMENT
AND STANDARDIZATION

WORKSHOP

27 February 1985

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APPENDIX 3

AGENDA

WORKSHOP

COMPOSITE MATERIALS TEST METHODS DEVELOPMENT
AND STANDARDIZATION

INSTITUTE FOR DEFENSE ANALYSES
WED., FEBRUARY 27, 1985

AGENDA

9:00	Introduction and Review of Survey Results.	S. L. Channon	
9:30	Short Presentations		
	ASTM Committee D-30	W. Stinchcomb	V.P.I.
	MIL HDBK 17	P. Doyle	AMMRC
	MIL STD 1944	F. Traceski	AMMRC
	NASA/Industry SPEC	J. Davis	NASA
10:00	BREAK		
10:15	High Temp. Composite Testing, Standards	P. DiGiovanni	Raytheon
	JANNAF Motor Case Test Methods	A. Munjal/ P. Niedzielski	Aerojet
	S.P.I. Standards & Certif.	J. McDermott	SPI
	Others		
11:00	Workshop Goals		
11:15	Selection of Test Methods/Materials		
12:00	LUNCH		
12:30	Scope of Testing Program		
1:30	Cost Estimates & Funding Sources		
2:30	Organization/Participation		
3:30	BREAK		
3:45	Management and Documentation		
4:45	Summary and Action Items		
5:00	ADJOURN		

APPENDIX 4

SURVEY OF TEST METHODS

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APPENDIX 4

SURVEY

OF

NEEDS

FOR

COMPOSITE MATERIALS

TESTING METHODS

STANLEY L. CHANNON

February 27, 1985

INSTITUTE FOR DEFENSE ANALYSES

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SURVEY OF NEEDS FOR COMPOSITE MATERIALS TESTING METHODS

INTRODUCTION

In the early development of composites, the materials were characterized by well established test methods which were generally used for monolithic materials. As the materials improved and applications became more sophisticated, different segments of the industry developed individual test methods for a variety of reasons. This has resulted in a plethora of methods with limited universal acceptance.

At the DoD-sponsored colloquium on Composite Materials and Structures - Standardization, Qualification and Certification held on May 8-10, 1984, the conferees identified test methods for composite materials as one of the highest priority items needing attention in the standardization and qualification of composites. The establishment of standard test methods and the development of new methods, where none exist or are presently unsatisfactory, was considered to be an essential prerequisite for the generation of a reliable data base for composites. In turn, it was expected that the entire composites industry would benefit from the accomplishment of this goal.

As a first step in addressing the subject of test methods in more detail, a questionnaire (Appendix 1) was prepared jointly by IDA and ASTM and was sent to all attendees at the Colloquium and to several other interested organizations to determine the prioritized interest in certain tests, the need for additional tests, interest in participating in the development of tests, opinions regarding ASTM and government involvement in test methods and other comments. Fifty-one responses were received from about 100 organizations, including materials suppliers, fabricators, designers, and government organizations throughout the United States.

This report summarizes the general results of this survey, preserving the anonymity of the respondents.

RESPONSES TO SURVEY QUESTIONS

1. Priority Listing of Test Methods in Need of Development or Improvement.

The questionnaire listed a number of test methods which were generally considered to be deficient in some respects. Participants were requested to rank these tests in order of relative priority. Table 1 summarizes the responses in terms of the total number of preferences for each priority level and test method.

As expected, the priorities vary with different applications. However, the overall interest in certain types of tests is indicated by the total number of high priority choices. Table 1 also shows the total number of preferences in the top six and the top ten priorities. It is anticipated that these test methods would receive the greatest attention in any future plans for test method development and standardization. Several other test methods were also suggested by some respondents as candidates for consideration; these are merely listed without priorities being indicated since they were mentioned by only a few respondents.

First priority was assigned to compression testing by 21 respondents. The next most frequently mentioned top priority item was toughened resin testing (10 votes), followed closely by specimen preparation (9 votes), shear tests (8 votes) and NDT (7 votes).

Cumulative votes for the tests ranking in the top 6 and top 10 priorities as summarized in Table 1 resulted in the following order of preference:

CUMULATIVE VOTES FOR EACH TEST

Top 6 Priorities		Top 10 Priorities	
Compression	42	Shear	45
Shear	39	Compression	42
Specimen Prep.	38	Specimen Prep.	42
NDT	27	NDT	35
Toughened Resin	25	Chem. Charact.	32
Chem. Charact.	24	Toughened Resin	31
Bolt Bearing	20	Bolt Bearing	29
Flexure	15	Flexure	27
Fiber Count	15	Fiber Count	23
Thermal Expansion	14	Moisture Content	22
Moisture Content	12	Thermal Expansion	21
Ply Count	9	Ductile Fiber Testing	19
Ductile Fiber Testing	8	Ply Count	17
Impact Testing	4	Impact Testing	4

From this ranking, a selection may be made of certain tests for early evaluation, depending upon the amount of participation and support available.

2. Interest in Assisting in Test Development.

This question sought to determine the capabilities and willingness of organizations to participate in testing programs by conducting tests, providing materials or any other support without actually making a commitment at this time. The responses are presented verbatum in Table 2.

There were 37 affirmative replies and 11 negative replies; however, some of the negative replies were based on lack of facilities for testing, rather than lack of interest. Among the affirmative responses, a large number of organizations expressed interest and capability in conducting the higher priority tests. Thus, the opportunities for conducting statistically meaningful round-robin testing appear to be very promising.

3. Need for DoD and/or NASA Support for Test Method Development.

The response to this question was overwhelmingly affirmative (Yes - 43 votes, No - 6 votes), as might be expected. The comments accompanying the responses are included in Table 3 and indicate that several options should be considered in inviting or encouraging support from these agencies. These suggestions are summarized as follows, but not in order of priority:

a. Through grants to ASTM.
b. DoD Funding
    1. Via Laboratories
    2. Expansion of MIL-HDBK 17 program
    3. Funding to NASA
    4. Add-on to production programs
    5. Subsidy to ASTM
    6. Round-robin testing
    7. Special equipment
c. NASA Funding
d. DoD and NASA Cooperative Program
e. Contract R&D
f. Universities, with industry

There is clearly a need for financial support to establish standard test methods. Several respondents expressed the opinion that a concerted effort should be made to develop and publish standard test methods and insist that these be used in government funded programs in which composites are used. The options listed above need further study to determine the best approach.

4. ASTM Role in Non-Destructive Testing.

This question addressed the need for ASTM to take a more active role in establishing standards and methods for non-destructive testing (NDT) of composite materials. NDT methods for composites are still in a relatively early stage of development, but it is often necessary to rely on NDT to evaluate the structural condition of composite hardware. While ASTM has a committee on non-destructive inspection, the application to composites has not received much attention, to date.

While the responses listed in Table 4 were strongly positive in having ASTM become more active (Yes - 34 votes, No - 10 votes, Not sure - 3 votes), specific recommendations on the ASTM role were not well defined. The respondents recognized the problems associated with an ASTM Committee attempting to develop NDT standards in this dynamic technology but also felt that ASTM may be the logical focal point for dissemination of information and direction. It was also suggested that support from industry and government is needed for ASTM to achieve results in a timely manner.

5. ASTM Role in Chemical Characterization.

This question sought to determine whether ASTM should be involved in developing methods to chemically characterize the matrix constituents of composite materials. The responses in Table 5 were varied and many were non-specific. Although the overall response was overwhelmingly positive,(Yes - 34 votes, No - 13 votes, Not sure - 5 votes), the comments indicated that ASTM's role should perhaps be limited. Some respondents pointed out that standard procedures are available for chemical characterization but are not universally employed. Others felt that further standardization is needed and that ASTM could be effective in organizing round-robin testing programs and issuing outlines of methods, whereas some felt that ASTM was not the most appropriate group. Some commented that the materials suppliers have a concern about chemical characterization.

6. ASTM Role in Practices for Specimen Preparation.

The importance of test specimen preparation was recognized by most respondents since this is believed to be an area of vital concern in the generation of property data. The responses in Table 6 showed an overwhelming majority of 45 votes in favor of and only 5 votes opposed to the idea of ASTM developing recommended practices for specimen preparation. Many of the favorable responses were accompanied by comments which emphasized the importance of proper specimen preparation. Some negative responses were based on the opinion that this should be included as part of the test method development or should be related to processing and manufacturing. One negative respondent felt that a government/industry task force should be responsible for these procedures.

7. Need for Certification of Testing Laboratories.

At the present state of the composites industry, a wide variety of test methods exists and data are not mutually interchangeable from laboratory to laboratory. In order to reduce the multiplication of testing required to qualify materials for various end uses, the concept of certified laboratories has been proposed. Under ideal circumstances, the test data emanating from certified laboratories would be presumed reliable and acceptable for many applications. The question posed in the survey sought to determine whether there was sufficient interest and need throughout the industry to consider a testing laboratory certification program.

The responses in Table 7 were again overwhelmingly in favor of such a certification program (Yes - 31 votes, No - 15 votes, Not sure - 4 votes). Some of the negative opinions were based on uncertainties related to the implementation of the program rather than lack of merit.

The positive responses were generally substantiated by comments emphasizing the advantages of certified laboratories to small companies which did not have in-house laboratories and to larger companies for checking their in-house capabilities.

Some respondents raised appropriate questions about the mechanics and funding of certification. It is recognized that this is a complex matter with many factors to be considered and attitudes to be modified but the indications from this survey are that it is desirable and may, in fact, become essential. A special task force would be needed to put the concept into practice.

As an editorial comment, this question may have been a little confusing. The intent was to determine the need for certifying laboratories, whether they be independent laboratories or laboratories within the various segments of the composites industry. It was not intended that a single certified laboratory be established as the sole source of certified composites data. This would not satisfy the needs of the industry.

8. Use of Certified Test Laboratories, if Established.

This question was based on the hypothetical assumption that certified testing laboratories were available and asked whether such laboratories would be used. The responses in Table 8 were similar to those for the previous question regarding the need for certified laboratories. There were 36 affirmative votes, 13 negative votes and 1 not sure.

Many positive responses had no comments to support their position. Several respondents said that they would use independent certified laboratories to supplement their in-house capability, to cross-check in-house data and if economically more attractive than in-house testing. In some cases, they would use independent laboratories only if required to do so contractually. Most of the negative responses were based on the fact that they have adequate in-house laboratories or were not involved in testing.

9. Establishing Criteria for Certifying Laboratories.

As recognized in Section 7, one of the major tasks to be confronted in implementing a certification program for the laboratories is the establishment of criteria for certification. The question was asked whether ASTM should be involved in setting up these criteria, in cooperation with the Government and industry.

Although the responses in Table 9 indicated a favorable opinion toward ASTM acceptance of this role, (Yes - 30 votes, No - 17 votes, Not sure - 3 votes), the comments accompanying some of the affirmative votes also expressed some apprehension. Many responses were without comment. Thus, the endorsement was not as strong as the number of votes indicated. Concerns from both affirmative and negative respondents centered around the extent to which ASTM should participate in this effort; some felt that the ASTM role should be limited to defining standards rather than acting as a certifying organization while others expressed the opinion that some government agency should do the certification.

10. Other Areas for ASTM Attention.

The questionnaire also asked for suggestions on other areas of composite materials technology that ASTM should be addressing. A number of suggestions were received and are listed as stated in Table 10. A summary of these areas includes the following items, not listed in order of priority:

a. High temperature materials testing
b. Thermoplastics
c. Processing Standards
d. Impact
e. Fatigue, Compression Fatigue
f. Toughened resin systems
g. Filament Wound Structures
h. Hot, wet environmental testing
i. Expansion of scope to include industrial composites
j. Continuation of workshops, seminars, etc.
k. Consistency/completeness of Reporting

Conclusions.

Based on the results of this survey, which is believed to be reasonably representative of the advanced composites segment of the composites industry, the following conclusions may be drawn:

1. This survey confirmed the strong interest in and need for standardized test methods for composites.

2. There is strong interest by a number of responding laboratories in participating in a test method development program, although the levels of involvement have not been determined.

3. DoD and/or NASA support was recommended for the test development program. Specific areas of support were suggested, such as round-robin testing, but details of the support levels and mechanics need to be addressed.

4. ASTM was encouraged to take a more active role in non-destructive testing methods and standards for composites.

5. ASTM was also encouraged to become involved in chemical characterization of composites to a limited extent.

6. Test specimen preparation methods are in need of standardization and ASTM was thought to be an appropriate focal point for issuing standard practices.

7. Certified testing laboratories are needed and can provide independent data sources.

8. Certified laboratories would be used to some extent by industry, if available.

9. ASTM may play a role in establishing criteria for certification of laboratories but should not be a certifying organization.

10. A number of other areas were identified in which ASTM could become the focal point for dissemination of standard procedures.

Recommendations.

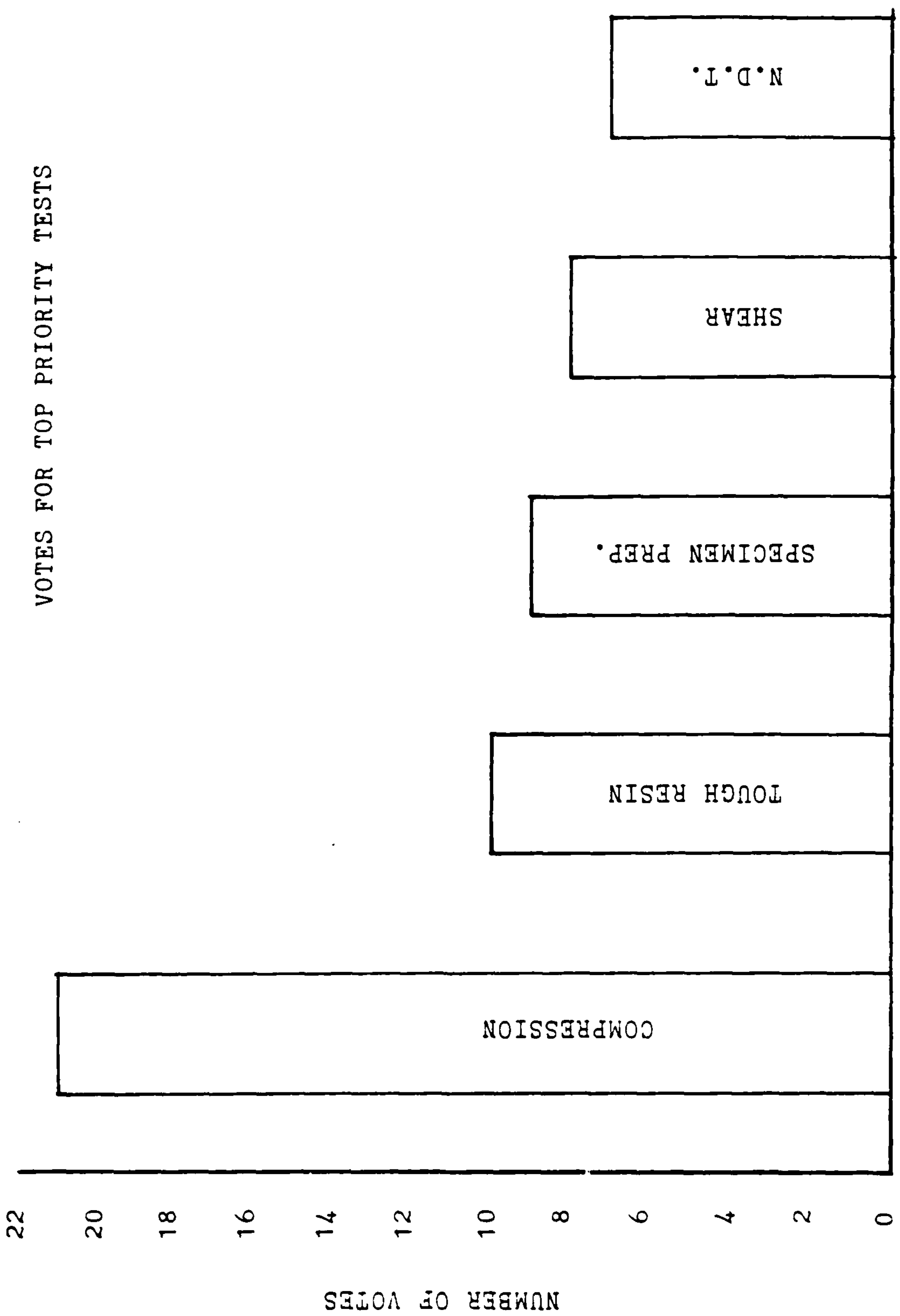
This survey identified several areas of test method development and standardization which received strong endorsement and should therefore be pursued in further detail. As a next step in formulating future plans, a workshop has been organized to address the issues involved. This workshop will be held at the Institute for Defense Analyses on February 27, 1985 and its purpose is to outline a general plan for test method development which will cover the test methods, material types, scope of testing development studies, cost estimates, organization, participation, and management of such a program. A key factor will be the sources of funding for the entire program. Further specific recommendations are expected to be forthcoming from this workshop.

To a large extent, the results of this survey indicate a need for further action by ASTM. It is therefore recommended that those items be reviewed by ASTM management for consideration and possible adoption.

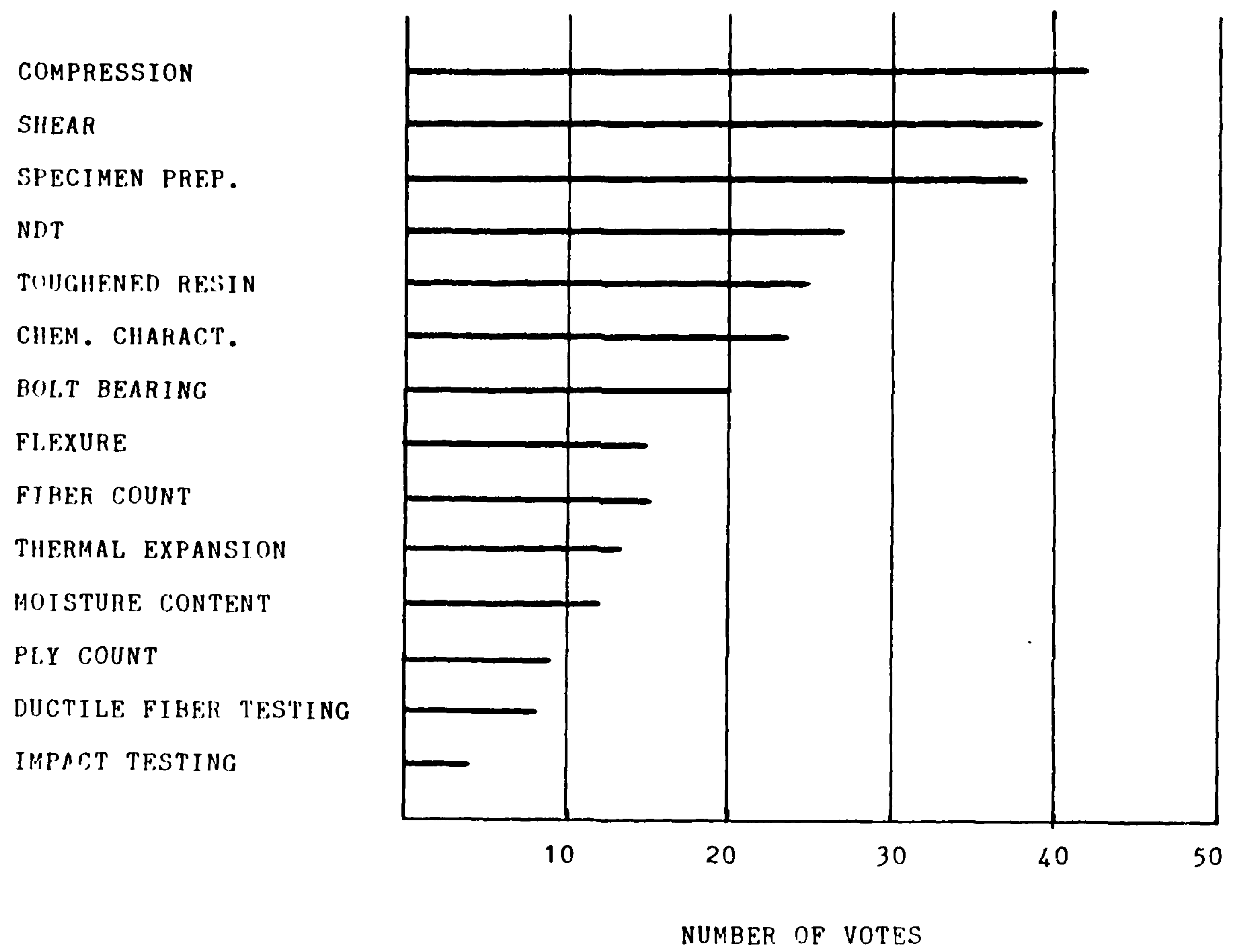
TABLE 1

TEST METHODS PRIORITIES

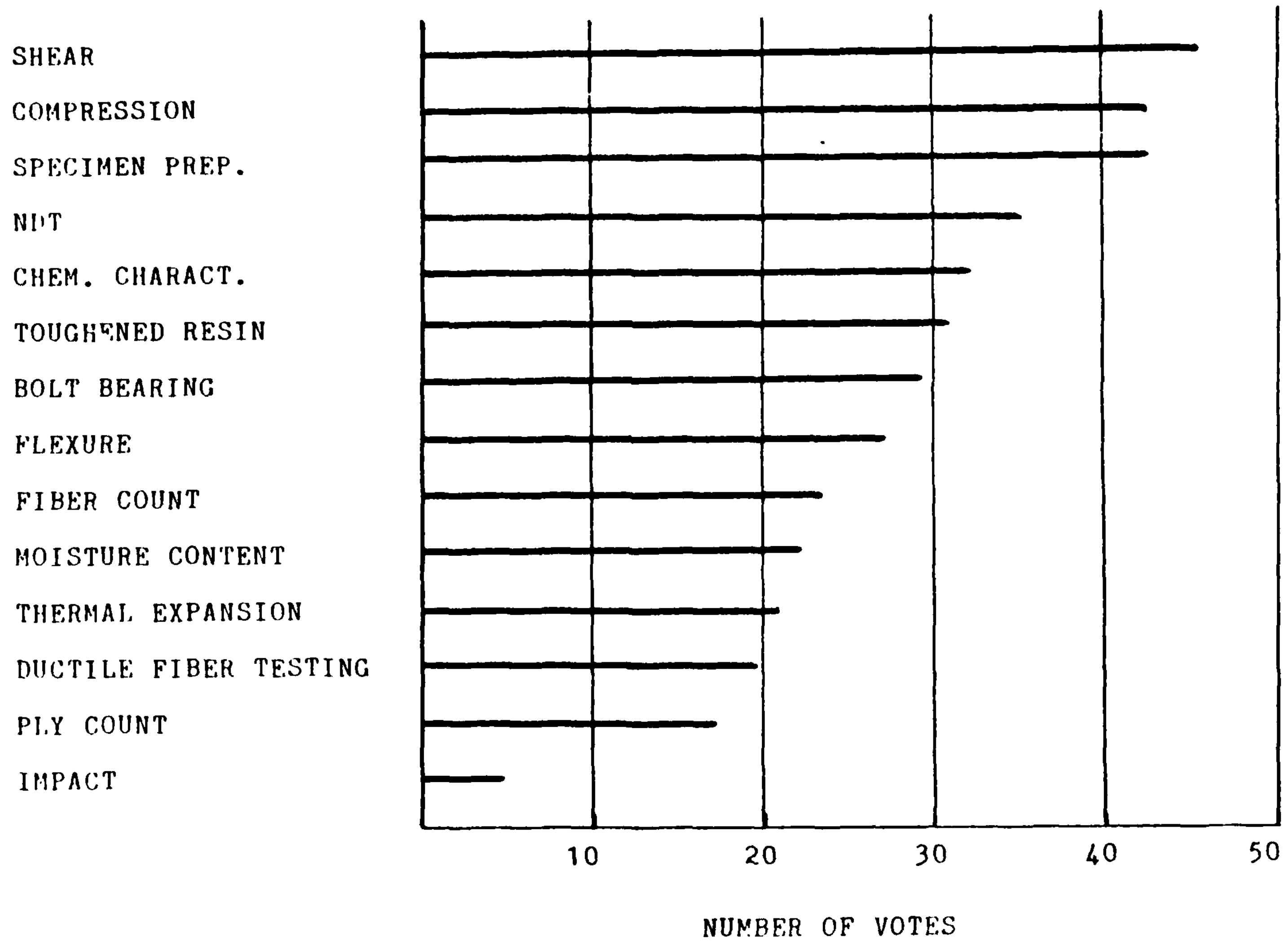
TEST	PREFERENCES FOR PRIORITIES INDICATED																	CUMULATIVE	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Top 6	Top 10
SHEAR	8	12	7	4	5	3	3	3										39	45
COMPRESSION	21	7	4	5	3	2												42	42
TOUGH RESIN	10	6	4	1	3	1	3	1		2	3	2	1					25	31
C.T.E.	2	2	4		5	1	1	1	4	1	2	5	2	1	1	1		14	21
DUCTILE FIBERS		1	3	3	1		1	3	3	4	4	1.	1	1				8	19
FLEXURE		2	5	1	6	1	4	1	1	5	1	1	2	1	1		1	15	27
NDT	7	6	3	5	4	2	3	2	2	1	1	1				1		27	35
CHEM.CHAR.	1	7	4	2	3	7	2	1	3	2	1	1	2					24	32
SPEC. PREP.	9	8	6	6	3	6	2	2				1						38	42
BOLT BEARING	2	5	7	3	2	1	3	4	1	1	3	1	3					20	29
PLY COUNT	1	1	2	3	1	1			3	5	3	4	4	1	1			9	17
FIBER CONTENT	1	1	4	3	3	3	2	1	3	2	2	1	3		1			15	23
MOISTURE	1	2	2	2	4	1	3	3	3	1	3	2	3					12	22
IMPACT	1	1	1			1												4	4
ENVIRONMENT								1										0	1
DAMPING									1									0	1
DIELECTRIC SPECTROSCOPY											1							0	0
DOUBLE LAP SHEAR		1																1	1
T_G-DRY, WET.			1															1	1
FRACTURE				1	1														
FATIGUE/ENVIRON.																			


VOTES FOR TOP PRIORITY TESTS
N.D.T.
SHEAR
SPECIMEN PREP.
TOUGH RESIN
COMPRESSION
0
2
4
6
8
10
12
14
16
18
20
22
NUMBER OF VOTES

CUMULATIVE VOTES FOR TESTS IN TOP 6 PRIORITIES



CUMULATIVE VOTES FOR TESTS IN TOP 10 PRIORITIES



RESPONSES TO QUESTIONS

NO.	QUESTION	RESPONSE		
		YES	NO	NOT SURE
2	Interest in Assisting in Test Development?	37	13	-
3	Should DoD and/or NASA be Asked to Support?	43	6	-
4	Should ASTM play more active role in NDT?	34	10	3
5	Should ASTM be involved in chemical characterization?	34	13	3
6	Should ASTM develop recommended practices for test specimen preparation?	45	5	-
7	Is there a need for having test labs certified?	31	15	4
8	Would you use independent certified labs?	36	13	1
9	Should ASTM set up criteria for certifying labs?	30	17	3

TABLE 2

WOULD YOUR ORGANIZATION BE INTERESTED IN ASSISTING IN THE DEVELOPMENT OF ANY OF THESE TEST METHODS?

Yes	Compression and shear. Perhaps test specimen preparation.
Yes	Test methods related to the matrix dominant properties/performance.
Yes	Compression, shear, sample prep, CTE
Yes	Compression, impact, toughened matrix tests, chem. characterization, NDI, shear, bolt bearing, ductile fiber, rheology, dielectric.
Yes	Bolt Bearing.
Yes	Test Specimen Preparation. Double-Lap Shear Tests. Toughened resin matrix. Fiber content in composites with Polymeric Fibers. Coefficient of Thermal Expansion. Chemical Characterization.
Yes	High Priority Test Methods.
Yes	Fiber content, test specimen preparation, chemical characterization, tests applicable to more ductile fibers, toughened resin matrix, and compression testing.
Yes	Test specimen prep., chemical characterization, shear, compression.
Yes	Shear, chemical characterization.
Yes	
No	
Yes	
Yes	
Yes	Test specimen preparation.
Yes	Compression
Yes	
Yes	Willing to supply materials. Our testing capability is very limited.
No	
Yes	Extent - To be determined.

Yes Different levels/segments of our organization would address chemical, mechanical and physical test methods.

Yes Coefficient of thermal expansion, Compression, Specimen Preparation.

Yes Chemical characterization, Moisture content

Yes NDT, CTE, Specimen Preparation for MMC.

Yes Compression, Shear.

No

No We are a policy organization.

No

Yes Metal Matrix Tests (All)- Compression, Shear, CTE

Yes Wet Tg, Shear, Post Impact Compression.

No

No

No

Yes Compression, *In-plane* & *Interlaminar* Shear, Bolt bearing.

Yes Any.

Yes All.

No We do not have lab. facilities; we are an information analysis center.

No Most of the materials discussed are not applicable to our operation.

Yes All or most of them.

Yes Compression, Toughened resin matrix, Fiber content in composites with Polymeric Fibers, Non-destructive Test Methods.

Yes

Yes I think we have a clear and important role to play in such an effort.

Yes Participation in review of methodology for test sample preparation.

Yes Compression, Shear, Fracture.

No

Yes Yes, but not at this time.

Yes Chemical characterization, compression, toughened resin matrix, shear, void content/NDI.

Yes Toughened resins, test specimen preparation, chemical characterization.

TABLE 3

SHOULD DOD AND OR NASA BE ASKED TO SUPPORT THE DEVELOPMENT OF THESE METHODS? (IF YES, HOW SHOULD DEVELOPMENT BE SUPPORTED?)

Yes NASA should do it as a technology methodology development.

Yes DOD and/or NASA could provide contract money for test method development through their respective laboratories.

Yes Through "No-strings attached" grants to ASTM.

Yes Funding is required. Current voluntary activities are very slow.

Yes NASA has supported development of test methods and a specification for toughened materials as a part of technology programs on test methods. Additional programs should be funded by the DOD, but with wider Industry participation.

No

Yes Direct contracting to ASTM.

Yes All government organizations (like NASA, AMMRC, Navy, etc.) should agree on common guidelines to develop a specification and then prepare a guideline document like NASA Ref. Publication 1092 to be developed into a formal specification.

Yes $ for modeling of configurations (ie. shear for non-unidirectional composites).
$ for experimental verification.
Workshops for contractors to make them aware of the standards.

Yes While there are a number of scientists at NASA who feel this effort should be supported, management tends to give test development very low priority. Should be approached through NASA Headquarters.

Yes

Yes Expand the financing of groups such as MIL-HDBK-17 to allow such method development.

Yes Via Universities and Government grants.

Yes

Yes Through contract research and development. ASTM procedures are very lengthy due to the voluntary nature of the "round-robin" procedures.

Yes Someone should serve as coordinator.

Yes Full blown comparative analysis and test of each test specimen for a given failure mode, e.g. in-plane shear.

No Participate, yes. Support financially or as principal research site, no.
e.g., we hope NASA labs would be one of several in round-robin testing, but not exclusive lab.

Yes It would be to the benefit of the DOD to have standardization. The DOD should fund NASA to coordinate the program.

Yes Funded programs/Multiple awards for round-robin.

Yes Proposed MIL-STD-1944 should be one standardization document which contains standard test methods for composite testing, while MIL-HDBK-17 should concentrate on design data and test results for new materials. Justification for this course of action is contained in MIL-STD-962.

No DOD & NASA should cooperate and provide some support but they should not be asked to foot the whole bill.

Yes Direct funding.
Add-on to production programs.
Data gathering from previous contracts.

Yes

Yes Via funding and special testing lab. support. Also specialized NDT capability.

No Should be done in cooperation with universities & industry.

Yes I believe the support by DOD and NASA should be in having people attend and help where possible in ASTM. They really have done this in the past and should continue and expand this effort.

Yes Through participatioin on standards developing committees. By developing and coordinating Mil-Specs where appropriate.

Yes Yes in areas such as MIL-HDBK-17 for DOD and NASA. Also a close working relationship with the Testing and Inspection panel of JANNAF.

Yes DOD support. Direct subsidy to ASTM: ASTM would administer financial support through ASTM active sub-committee. Active members of sub-committees, with approval of their organization, would engage in round robin testing. The choice of those who could participate would be determined by ASTM Technical Committees , not by ASTM. The Technical Committee would be responsible for: (1) developing the test method, (2) over-seeing round-robin, (3) reviewing data of each participant and insuring test procedures have been followed, (4) issue a report on its findings together with recommendations for a new standard, no standard, etc. The Tech. Committee could not guarantee that a standard would result since only the ASTM membership through its vote could approve a new or modified standard.

Yes Of all the wasted time and money caused by non-standardization the most needless is repeating the same procedure 7 different ways to comply with 7 different qualification specifications. This reflects two problems: the fine details of test methods aren't standardized and no one wants to weaken an existing data base by changing to a new test method. The solution to the first problem is to gather industry and government representatives at a single meeting and not leave until a single procedure is defined in precise detail then have DOD fund round robin testing to confirm precision and accuracy. All future DOD or NASA contracts must demand that testing be done by those methods and the resultant data base be published, hence replacing the old data bases established with obsolete test methods.

No

Yes If there are to be standards, all data concerning these developments and validations must be published. This will be done by development under contract. The airframe industry is the end user of the design values and allowables developed from standard tests; therefore they should be contracted to do the development.

Yes Support development of methods by awarding contracts for said programs.

Yes Government involvement would help to insure acceptance of specific methods.
a. Agencies would be aware of advantages/disadvantages of particular methods vs. alternatives.
b. Government.

Yes Support round-robin costs.

Yes 1. NASA-Langley has done a good job in defining tests of toughened composites - these should be reviewed and discussed broadly for adoption by general industry.
2. Standardization of moisture test methods and analytic prediction of moisture content (diffusion analysis) could easily be pulled together from prior AFML work and presented as a standard by some University group such as U. of Dayton or U. of Washingon, or Springer at Stanford.

Yes Through support of ASTM, MIL-HDBK17 or similar group effort.

Yes Financial support for the purchase of special or unusual equipment to carry out the test methods.

Yes By sponsoring R&D programs in/with industry for the specific goal of developing a method suitable for adoption as a standard.

Yes

Yes Support via contracts and grants.

There are certain areas where test methods can easily be developed in a straight forward way. In other areas basic studies are needed to determine what to measure and how to measure it. Without this we could end up with more tests of little or no value. We have many of these now and they result in lots of wasted time and money.

Yes Government funded.

No

Yes DOD/NASA could release pertinent data from past and present programs to establish a baseline.
They could fund R&D programs in this area.

Yes Methods for reliability evaluation for high performance materials (extended property envelopes) are not fundamentally well established; R&D and mechanistic work will be required to develop acceptable industry guidelines.

Yes Thru jointly funded (DOD/NASA) R&D programs offered for competitive bidding. In other words, our Government should no longer gouge technology/data from industry but should instead pay its way.

Yes A funded program should be developed whereby a monitoring organization representing government, industry, academia, and ASTM would review test methods and, through round robin testing, select or establish standard test methods. The test methods would be published and only data generated by these methods would be accepted for intercompany exchange or government funded programs.

Yes NASA-Langley is already coordinating the effort of developing a standard specification for toughened composite materials. Individual to contact is Andy Chapman.

Probably. 1. ASTM is the natural and current focus for testing, but the process is much too slow. ASTM needs to recognize and correct this problem, probably by insisting on more dynamic committee leadership, or by acquiring early help from SACMA and other industry groups.

2. Other options are ASM and American Society for Non-Destructive Testing which have a more complete background in NDT, if not composite materials.

Yes With DOD encouragement and support if information will improve military material.

Yes

Yes It would be just a part of ASTM's business/charter/tests/ responsibility.

Yes

Yes Need better focus and time schedule.

\- I would suspect yes.

Yes

Yes

Yes Coordination between DOD, NASA, FAA, ASTM, AMS (SAE), and others is essential to avoid duplication of effort and to ensure standard procedures. Current costs of qualifying components are already too high.

Yes ASTM well positioned to help; I'm not sure that they can work fast enough (with concensus approach) to address high priority needs, however.

Yes What better alternatives exist? This organization (ASTM) has been the Hallmark Group in developing testing standards for many types of plastic materials for years; seems to be a most logical extension of their expertise to develop non-partison approaches to NDTE.

Yes 1. As part of the standardization procedure noted in 3.
2. Function as a leader in educating personnel to uniformly interpret data results.
3. Assist in the methods for generation of standard defect panels for calibrating NDI equipment.

Yes

TABLE 4

SHOULD ASTM PLAY A MORE ACTIVE ROLE IN DEVELOPING NON-DESTRUCTIVE TESTING METHODS FOR COMPOSITES?

-	Not sure - again I think DOD or NASA should sponsor generic type investigations. Unfortunately everybody is using ultrasonics and not that much is being done to develop faster, less costly methods. ASTM should form a committee to evaluate results and suggest standards.
Yes	
Yes	
Yes	Lack of uniformity in basic equipment will make this difficult, plus the dependence on operator skills. Requires close co-ordination with suppliers, contractors and ASNT.
Yes	
Yes	
Yes	Only from a Standardization/Documentation standpoint.
No	
Yes	Not to define "the" method since NDE is changing as new technologies are developed but to encourage consistent methods within a technology.
Yes	
Yes	
Yes	
Yes	
Yes	
Yes	In a minor role.
Yes	
Yes	....provided it receives more active participation from industry and "real world" users. There is an impression that present ASTM membership in these fields is "too academic". This may or may not be justified.
Yes	
No	

Bernie Strauss of AMMRC should be consulted on this matter. My inclination is to tend toward a "no" answer because the DOD currently has a strong program going in this area (NDTI)

No

No ASTM only sponsors symposiums to present data.

No

Yes But must be done in concert with producers of material to maintain practicality.

? They have an NDI committee. How active?

Yes ASTM should be the focal point for all test method development.

Yes

Yes The time has come for ASTM to begin observing the techniques currently being used; however the techniques are so widely varied that ASTM probably won't be involved in the forefront of the activities. The DOD YEARLY CONFERENCE ON NDT/NDI would be a good organization to monitor activities.

Yes Yes. They are already doing it now but not doing it well. Unfortunately since no financial support is given organizations for conducting round robin testing, tests are often "boot-legged" with little or questionable documentation available and no means of controlling each participant (after all, they're performing the tests for "nothing".) As a result, some very questionable ASTM test standards have resulted.

No The non destructive testing technology is still too new and poorly understood to be effectively standardized by a general industry group such as ASTM.

No

No

No In developing - No.
In standardization - Yes.

No ASTM is doing as much as they can already, within the constraints imposed by government and industry.

Yes

TABLE 5

SHOULD ASTM BE INVOLVED IN DEVELOPING METHODS TO CHEMICALLY CHARACTERIZE MATRIX MATERIALS?

-	Not sure at this time.
Yes	Standardized procedures are needed.
Yes	Believe government agencies need to prod companies to support ASTM in this endeavor.
Yes	This is too small an industry for ACS.
No	ASTM is not the most suitable agency in this area. It appears the Bureau of Standards would be a good choice.
Yes	
Yes	Standardization of test techniques and methods.
Yes	A test technique within ASTM charter.
No	Government industry task force with a group of no more than 10 persons should develop nondestructive testing methods.
No	Standard test methods are available for chemical characterization of polymers, metals and ceramics. The need is to apply the proper standard methods to a given matrix.
Yes	
Yes	Certainly.
Yes	There are far too many reports/papers that are published where the analytical methods employed are insufficient.
Yes	
No	This area should be covered by the material supplier and the user.
Yes	Standardize.
Yes	
Yes	From the standards standpoint.
No	Shouli be responsibilit, o- resin supplier.
Yes	
Yes	As users require.

No I cannot see a reason for further standardization of chemical characterization techniques, nor the development of new techniques. The techniques now in place provide adequate "finger printing" of materials.

Yes

Yes Standard methods for HPLC, GPC, DR-FTIR, UV and other instrumental techniques should be prepared by ASTM. Standard chromatograms and spectra should be prepared in material specifications.

Yes ASTM should be involved via the "round robin" route to verify tests that support their classification schemes.

Yes Metals (including ones used in metal matrix composites) currently meet ASTM standards. Therefore, resins in organic matrix composites should also meet ASTM standards.

No

\- Either way.

Yes

Yes I believe that ASTM should have practices or methods that outline the techniques and give the problems that can come up. Each matrix material is unique and will have its own problems.
Don't know. Not technically familiar.

Yes

Yes But should be properly funded to do so.

No

No

No

Yes

Yes

No ASTM is not generally technically qualified for this activity. SAMPE or SPI would be better, or ACS.

Yes A multidiscipline approach should be adapted to characterizing organic matrix prepregs and matrix materials. It appears that exclusively chemical approaches will be inadequate to characterize all compositions and mechanical and physical properties testing are to be considered to establish practical and efficient standards at lowest costs.

Yes

Yes I am not so sure about ASTM's involvement here; also, this test, although necessary, is low on my priority list; perhaps a chemical organization is better suited to direct this effort?

No

?

I don't think this is necessary but I don't feel strongly on this.

Yes See also SAC/AMS specifications ARP1610, ARP1611.

Yes The resin manufacturers will resist this.

Yes

No opinion.

Yes What better alternatives exist? This organization (ASTM) has been the Hallmark Group in developing testing standards for many types of plastic materials for years; seems to be a most logical extension of their expertise to develop non-partisan approaches to NDTE.

Yes Standardization of procedures is urgently required.

Yes - - -

No Too many different resin systems.

TABLE 6

SHOULD ASTM DEVELOP A RECOMMENDED PRACTICE FOR TEST SPECIMEN PREPARATION?

Yes	
Yes	There is a need for this in specimen preparation of cured laminates, tested for example in compression or tensile strength/modulus.
Yes	This is critical for all Mechanical Tests.
Yes	A determination is needed of which tests are sensitive to specimen preparation; in other words first demonstrate a need. Laminate quality may be a more important factor in many cases.
Yes	
Yes	
Yes	
Yes	
No	Government industry task force with a group of no more than 10 persons should develop methods.
Yes	Different materials have different surface treatment sensitivities. Recommendations should be material specific.
Yes	
Yes	
Yes	
Yes	
Yes	It is very important to have consistent specimen preparation to achieve the maximum values for composites.
Yes	
Yes	
Yes	
Yes	Should go hand in hand with test method development.
	No opinion.
Yes	
Yes	

No Test specimen preparation for a particular test should be included in the standard for that test.

Yes

Yes Specimen preparation can play a role in the measured properties and specimens should meet certain standards.

Yes

No Because many shops have individually worked out their own techniques - but ASTM could set basic requirements such as surface finishing tolerances!

Yes

Yes I feel strongly that this is needed. Specimen preparation can influence results appreciably.

Yes If appropriate.

Yes For basic lamina and laminate uniaxial and crossply mechanical properties; but every company is going to have certain special tests developed to test their own unique products.

Yes In effect, there are no recommended procedures for test specimen preparation that are followed by industry and laboratories. Test specimen preparation, geometry, processes etc. have evolved from a very shaky basis. None or very little documentation is available to support recommended ASTM specimen preparation. As a result, reports, journal articles, contract testing are performed using a variety of test specimens, often with no justification.

Yes

No

Yes

No Specimen preparation should be related as closely as possible to the specific processing and manufacturing procedures a contractor expects to use in his products.

Yes

Yes This is key in compression testing and moisture testing of composites.

Yes

Yes

Yes It's ASTM's responsibility to do so.

Yes

Yes

Yes The development of such information is necessary and perhaps ASTM has a role to play.

Yes To eliminate variability.

Yes

Yes

Yes With appropriate reservations about time needed.

Yes What better alternatives exist? This organization (ASTM) has been the Hallmark Group in developing testing standards for many types of plastic materials for years; seems to be a most logical extension of their expertise to develop non-partison approaches to NDTE.

Yes

Yes Machining, Tabbing etc. Test Specimen preparation is critical to attainment of good, meaningful test results.

TABLE 7

IS THERE A NEED FOR HAVING TESTING LABORATORIES CERTIFIED FOR TESTING COMPOSITES?

Yes	Most of the varied test results on composite materials are not the result of material variability. It is the result of variable specimen preparation, alignment & loading/gripping methods. This is critical.
Yes	Such laboratories would be useful for testing composites in final form (after cure).
Yes	Who would certify? This could be a problem in this concept.
-	We waive this question. Standardized criteria and methods are needed first (Item 9) before lab certification requirements can be defined.
No	
Yes	Companies too small to have "any" or "adequate" testing equipment would be served well by certified labs. Also, to minimize the "bias" factor or to verify in-house data, an independent certified lab could be useful to all industries working with composites.
No	
No	Qualification or capability to perform SPEC-type testing is the proper approach, in lieu of other special "certification".
Yes	We feel a need to certify testing laboratories in their ability to test composite materials. We do not recommend a central "U L Type" testing laboratory used to certify materials.
No	If consistent test methods are used, a good testing lab can test composites as well as any other material.
Yes	
Yes	Availability of certified testing labs would be beneficial to small potential users of composites. These labs would also provide a "check" on the capability of in-house labs.
Yes	
Yes	
Yes	It would help to eliminate lab to lab variations and improve data validity.
Yes	

No

Yes

Yes Absolutely needed to minimize cost & speed certification.

No

Not at present. The high-tech/low volume of the industry provides adequate self-selection at present. If "commercial" labs smell opportunity in the future, however, they will emerge as participants and then there will be a need for certification.

Yes

Yes

No I'm not certain that certification of testing labs would be beneficial. I am in favor of a standard qualification test matrix which could be covered in a military standard such as the proposed MIL-STD-1944 which is now being coordinated. Establishing only one certified lab would tend to centralize composites testing, when the current "megatrend" in the U.S. is toward decentralization. Decentralization promotes a dynamic process and prevents bureaucratic stagnation. Centralization is too controlled and restrictive. Furthermore, the cost of establishing a certified lab(s) or a certification process might even exceed the cost that this concept is trying to save. Qualification of materials should be conducted in accordance with the DOD SD-6.

Yes If a test matrix is to be established to qualify alternate materials or sources, a "certified" laboratory will be necessary to minimize qualification costs.

No Mil Handbook 17 may want to assure that laboratories meet certain standards in order to include that data in the handbook.

Yes

No

Yes

No My response is no because I'm not aware of this being done in other materials. The idea of certification for composites doesn't do much for me.

Yes If appropriate. Depends on user's acceptance of the results from a testing laboratory.

Yes Yes, for basic mechanical testing for physical properties. However most organizations do some physical property testing and the cost of certifying all companies would probably be prohibitive.

No I don't know how the certification process would be implemented. Questions:
1. Who certifies labs?
2. How do they certify, i.e., what basis would be used?
3. There would result indefinite controversy over which test procedures are best, or acceptable.
4. Who would fund the certification process?
5. Suppose a lab claimed that their procedures were superior to ASTM's but were uncertified. Could they not sue in court that they were being artifically restrained, or were being "black-balled" in spite of their claimed superiority? Who would adjudicate their claim?

Yes If standardized test methods existed and were demanded for government qualifications, then a prepregger trying to qualify a system as a second source to AS4/3501-6 at McDonnell Douglas could have the test matrix run once at a certified testing lab and use the data to qualify at Lockheed, GD, Grumman, etc., as well.

Yes

Yes

No Maybe. The idea sounds good, but, unless there are economic advantages, I doubt if an aerospace contractor would turn loose any major portion of testing. Most companies have adequate facilities of their own for this type of testing.

No

Not sure. The need does not currently exist since there are few recognized standards and procedures. In future, if generalized specs are widely adopted and used, this could become important.

No opinion.

No

Yes Certification is bound to improve the quality of performance, increase data reliability and confidence.

Yes

Yes For both aerospace and industrial needs.

Probably useful.

Yes For qualified suppliers.

No

Yes Because testing of composites is quite a different operation than testing of metals.

No opinion.

Yes Primarily this will benefit those programs where testing represents a significant portion of overall cost.

Yes The main issues would be who would certify the laboratories (ASTM, DOD, FAA) and acceptance of the data by government agencies. If the laboratory prepares the specimens from supplied panels, then item 6 (standard specimen preparation) becomes mandatory. The test results are still dependent upon the method, albeit standard, operator skills and equipment accuracy.

Yes Too many different procedures - some with just subtle differences which have large effects.
As critical as testing is, requirements for certification of testing Laboratories would be valuable.

TABLE 8

WOULD YOU USE INDEPENDENT CERTIFIED LABORATORIES?

Yes	We are trying to use outside labs at this time.
No	We have a highly developed in-house analytical capability and a long history of resin analysis. We would see little use for such a laboratory for resin analysis.
Yes	
Yes	Currently used to handle work overloads.
Yes	If costs were lower than in-house testing costs and service was prompt, we would use independent laboratories.
No	
No	Our use would be very limited.
Yes	Assuming that "certified" means that the labs can perform spec. testing.
Yes	We feel a need to certify testing laboratories in their ability to test composite materials. We do not recommend a central "U L Type" testing laboratory used to certify materials.
No	I would use an independent lab irrespective of certification. I use people I feel are competent; certification does not necessarily give you that.
Yes	
Yes	
Yes	
Yes	
Yes	
Yes	
No	
Yes	
Yes	
No	
Yes	
Yes	

Yes

No Our testing labs are well-equipped to handle our testing needs.

Yes

No

Yes

Yes If available at reasonable price.

No

Maybe. We would use any lab which we felt was competent to do the testing we might want.

Yes For basic physical properties but would also do some basic quality tests in-house.

\- Instead of what other lab? Don't believe certified laboratories are feasible for reasons stated earlier.

Yes

Yes

Yes

Yes Even though we have our own testing laboratories, we still use ICL's for certified results.

Yes To the extent that they would supply expertise not currently available in my company or if it were significantly cheaper.

No Our preference is to develop adequate in-house capability due to cost and schedule requirements.

No Only if required by our customers - we prefer to do our own testing since extensive lab facilities must be maintained for development and QC, anyway. We would try to have our labs certified, however.

No Not applicable, do not have lab facilities.

Yes

Yes From a technical point of view, I would because they would be the qualified specialists, they would increase my confidence in the data they would generate; of course, economic conditions may sometimes govern the options in selecting the data generator/provider.

Yes

Yes

- Not applicable.

Yes

No

Yes As an aerospace manufacturer, we will be subject to stringent FAA guidelines. We would rather not have to develop in-house capabilities for all tests required.

Yes We would normally do our own work, but have worked with certified labs where it was more efficient.

Yes

Yes Only if schedule and manpower constraints prevented in-house testing.

Yes Occasionally to off-load or have independent third party opinion.

TABLE 9

SHOULD ASTM, WITH THE COOPERATION OF INDUSTRY AND GOVERNMENT, SET UP THE CRITERIA FOR CERTIFYING COMPOSITE MATERIALS TESTING LABORATORIES?

Yes	
Yes	
-	I question whether ASTM can do this.
Yes	ASTM should help define criteria, but should not become a licensing agency.
No	
No	
No	This seems to be a very difficult assignment for a voluntary technical society to achieve.
Yes	Assuming that "certified" means that the labs can perform spec. testing.
No	I recommend using committee from Item 4 or working committee from MIL HDBK 17.
No	ASTM and government should work to define standards, not certify competence, since this has not worked in the past.
Yes	
Yes	With caution - NASA is not a regulatory agency.
Yes	
Yes	
Yes	
Yes	
Yes	
Yes	
Yes	ASTM or other society.
No	
	Use great care before embarking. This project is potentially a great time-waster. Maybe the effort could build on existing programs, or at least learn by their example.

Yes

Yes

No I think emphasis should be placed on qualification of material composite systems, not on certification of testing laboratories. DOD qualification should be implemented in accordance with the SD-6.

No The ASTM process may be too involved. An Industry Association would be perhaps more adaptable to the task of establishing such criteria.

No

Yes

No

No

Yes If appropriate.

Yes

No Not workable. ASTM should set guidelines by developing adequate test procedures. Composite test procedures (standards) presently on books are outdated and inaccurate. Problem: The voluntary process simply doesn't work. Translated: You generally get at the best, what you pay for. Continually "boot-legging" round robin testing is doomed.

Yes This won't be necessary until test methods can be standardized.

Yes

Yes

Yes

Yes ASTM appears to be a very good choice to be the agency to certify testing laboratories. Certification should not be a one-time occurrence, but should require periodic checks or re-certification.

No

? I would prefer either a government certification (DOD, NASA, FAA) or an independent non-profit, such as Underwriter's Lab specifically devoted to this purpose.

No No lab facilities; are an information analysis center.

No This could entail the purchase of additional equipment to qualify for certification.

Yes With the longest experience in testing of composite materials, government, industry and ASTM are the best qualified to set up the necessary criteria.

Yes

Yes

Yes

No

Yes

No Doesn't fit ASTM activity particularly well, would probably take forever if ASTM group is normal size.

Yes

Yes Standard test methods/procedures need to be defined before laboratories can be certified. Perhaps the government should act as the certifying agency since they ultimately use the end product (DOD) or allow the product to be used (FAA).

Yes

TABLE 10

WHAT OTHER OR NEW AREAS OF COMPOSITE MATERIAL TEHNOLOGY SHOULD ASTM BE ADDRESSING?

Effect of chemical environment
Rheology
Dielectric spectroscopy
Impact behavior
Thermoplastic composites
Bolted and bonded repairs

Only testing.

Whatever test methods are put into the spec. by committee in item 3, should be incorporated in ASTM. ASTM needs to publish separate composites test procedure book.

Continued efforts in educational material & seminars. Work shops on characterization & testing, work books describing material factors influencing composite properties etc. Conceptual understanding is the most important factor to advance the state-of-the-art.

Processing Standards for major techniques in Polymer Matrix Composites.

Compression-Compression Fatigue Test standard test method.
Impact Damage Testing - damage zone detection methods.

Environmental effects testing durability.

The D30 charter to expand composites to other markets (beyond aerospace/defense) needs either review or commitment.

Higher temperature testing (<350.F)
Thermoplastic matrix composite testing

Material specifications for BMI, PPS, PEEK, Gr/Epoxy, PMR-15 and LARC-160 should be developed.

Standards for thermoplastic composites (i.e. melting point, degree of crystallinity, maximum use temperature.)

Consistency/Completeness of Reporting.

I would feel that the area of impact and fracture are techniques which should get some attention and efforts toward standards.

Should certainly keep abreast of the new high temperature polyimide systems being developed.

High temperature testing.
Material characterization (generically)
Material processing.
Environmental control as part of testing procedures.

A good method for wet Tg testing would be an extremely useful screening tool for developing and characterizing new high performance resins to be used in hot wet environment.

None

Testing of standard structural shapes
i.e.- I beams, T beams, etc.

Strain measurement on composites under hot, wet environment.
Summary of experiences obtained by various companies on specific test specimens or procedures.

Flammability!

List as presented seems pretty complete.

If they get involved in the foregoing - that will be plenty.

Thermoplastics.
Tougher and higher temperature matrix three-dimensional reinforcement to minimize delamination.

Viscoelastic test methods.

Test methods should more clearly delineate the procedural differences for testing composites, e.g., glass-reinforced versus carbon fiber-reinforced composites.

New materials evolving daily with specific needs; high performance materials have reliability problems which slow application; perhaps need generic methods for materials with extended property ranges that can be implemented more readily?

Measurement of dielectric composite properties.

Methods for toughened thermoplastic resin components.
Test methods for filament wound laminated structures such as fuselage sections and rocket motor cases.

APPENDIX 5

ASTM COMMITTEE ON COMPOSITE MATERIALS

W. W. Stinchcomb

ASTM COMMITTEE ON COMPOSITE MATERIALS

D-30 HIGH MODULUS FIBERS AND THEIR COMPOSITES

- SCOPE -- TO DEVELOP STANDARDS, SPONSOR SYMPOSIA, STIMUALATE RESEARCH, AND EXCHANGE TECHNICAL INFORMATION PERTAINING TO FIBERS HAVING A YOUNG'S MODULUS GREATER THAN 3×10^6 PSI AND COMPOSITES FABRICATED FROM THESE FIBERS.

- SUBCOMMITTEES
  - EDITORIAL
  - AUTOMOTIVE AND INDUSTRIAL COMPOSITES
  - RESEARCH AND MECHANICS
  - HIGH PERFORMANCE COMPOSITES

- TASK GROUPS
  - DELAMINATION AND DEBONDING (JOINT WITH THE ASTM FRACTURE COMMITTEE)
  - FRACTURE AND FRACTOGRAPHY
  - METAL MATRIX COMPOSITES

- LIAISON WITH ASTM COMMITTEES ON
  - PLASTICS
  - FATIGUE
  - FRACTURE
  - MECHANICAL TESTING (COMPRESSION)

- LIAISON WITH
  - MIL HANDBOOK 17 COMMITTEE
  - JANNAF ROCKET MOTOR CASES COMMITTEE
  - ARMY COMMITTEE ON TEST METHODS FOR POLYMERIC COMPOSITES (AMMRC) MIL STD 1944

TEST METHODS NEEDED FOR:

- COMPRESSION PROPERTIES -- IN BALLOT
- SHEAR PROPERTIES -- TASK GROUP
- FLEXURE PROPERTIES -- MODIFICATION
- DELAMINATION AND DEBONDING -- ROUND ROBIN/SYMPOSIUM
- METAL MATRIX COMPOSITES -- TASK GROUP/SYMPOSIUM
- ENVIRONMENTAL TESTING (ESP. HIGH TEMPERATURE) -- ?

ASTM SYMPOSIA
ON COMPOSITE MATERIALS

MARCH, 1985 -- HOUSTON, TEXAS

- TOUGHENED COMPOSITES, D-30 AND NASA-LANGLEY
- INSTRUMENTED IMPACT TESTING OF PLASTICS AND COMPOSITE MATERIALS, D-20

-- CHARLESTON, SOUTH CAROLINA

- FATIGUE IN MECHANICALLY FASTENED COMPOSITE AND METALLIC JOINTS, E-9

NOVEMBER, 1985 -- NASHVILLE, TENNESSEE

- TEST METHODS FOR METAL MATRIX COMPOSITES, D-30
- FRACTOGRAPHY OF MODERN MATERIALS, D-30 AND E-24

APRIL, 1986 -- CHARLESTON, SOUTH CAROLINA

- COMPOSITE MATERIALS - TESTING AND DESIGN, D-30

NOVEMBER, 1986 -- PHOENIX, ARIZONA

- TEST METHODS AND DESIGN ALLOWABLES, D-30

PROBLEM AREAS RELATED TO STANDARDS DEVELOPMENT FOR COMPOSITE MATERIALS

- Development of Voluntary, Consensus Standards is a Lengthy Process
  - -- TIME AND URGENT NEED VS. QUALITY, RELIABILITY, AND UTILITY
- Standard Test Methods Must be Kept Current
  - -- EACH METHOD IS REVIEWED, UPDATED, AND REVISED EVERY FOUR YEARS
  - -- CHANGES ARE MADE MORE FREQUENTLY WHEN NEEDED
  - -- NEW MATERIALS AND NEW TECHNOLOGY ARE BEING INTRODUCED AT A RAPID RATE
- **Nonuse and Misuse of Standard Test Methods for Composites**
  - -- STANDARDS USED INCORRECTLY
  - -- STANDARDS USED INAPPROPRIATELY
  - -- STANDARDS NOT USED
  - -- NONUSED OR MISUSED STANDARD TEST METHODS ARE OFTEN CITED TO 'VALIDATE' A DATA BASE
- Token Representation on Standards Writing Committees
  - -- FEWER PARTICIPANTS THAN MEMBERS

NEEDS FOR IMPROVED STANDARDS DEVELOPMENT

- IMPROVED DATA BASE FOR TEST METHOD DEVELOPMENT
  - -- THE CURRENTLY AVAILABLE, GENERAL DATA BASE IS INCOMPLETE
  - -- MORE ROUND ROBIN TESTING AND ANALYSIS
  - -- GOOD DESIGN OF ROUND ROBIN TEST PLANS AND PROCEDURES
  - -- MORE VOLUNTARY PARTICIPATION IN ALL ASPECTS OF TEST DEVELOPMENT AND STANDARDIZATION
  - -- TRACEABLE DOCUMENTATION ON DATA AND PROCEDURES

- STANDARD TEST METHODS FOR COMPOSITE STRUCTURES AND COMPONENTS
  - -- ARE SYSTEMATIC AND UNIFIED CERTIFICATION PROCEDURES TO BE USED?

- DOD/NASA ENCOURAGEMENT OF TEST METHOD DEVELOPMENT
  - -- TEST METHOD DEVELOPMENT AND ROUND ROBIN TESTING ARE OFTEN 'BOOT-LEGGED' BY INDUSTRIES AND GOVERNMENT LABS.
  - -- THE FINANCIAL COMMITMENT TO DEVELOP RELIABLE TEST METHODS IS SUBSTANTIAL.

- BETTER INTERACTION AND COMMUNICATION BETWEEN STANDARDS WRITING ORGANIZATIONS, INDUSTRIES, UNIVERSITIES, AND DOD/NASA AGENCIES
  - -- STATEMENT OF GOALS
  - -- DEFINITION OF RESPONSIBILITIES

DOD SUPPORT OF TEST METHOD DEVELOPMENT

- PRECEDENCE:

  NRC AND DOE HAVE SUPPORTED TEST METHOD DEVELOPMENT THROUGH GRANTS AND CONTRACTS FOR INTERLABORATORY TESTING, CONSUMER PARTICIPATION, MEETINGS, AND ACCELERATION OF TEST METHOD DEVELOPMENT.

- MECHANICS:
  - ASTM TECHNICAL COMMITTEE WRITES A DRAFT PROPOSAL
  - PROPOSAL REVIEWED BY ASTM STAFF AND LEGAL COUNSEL
  - WHEN APPROVED AND SIGNED BY ASTM, PROPOSAL IS SENT BY ASTM TO AGENCY
  - IF THE PROPOSAL IS ACCEPTED AND FUNDED, A COMMITTEE OF PRINCIPAL INVESTIGATORS (REPRESENTATIVES FROM THE ASTM TECHNICAL COMMITTEE) AND THE ASTM STAFF MANAGER IS APPOINTED TO OVERSEE THE TECHNICAL WORK AND EXPENDITURES AND REVIEW PROGRESS.
  - DELIVERABLES -- IN THE STATED TIME FRAME, THE TECHNICAL COMMITTEE WILL DEVELOP A 'STATE-OF-THE-ART, CONSENSUS <u>DRAFT</u> TEST METHOD'. CANNOT GUARANTEE A CONSENSUS <u>STANDARD</u> TEST METHOD IN THE TIME FRAME OF THE GRANT/ CONTRACT. WILL BALLOT THE DRAFT TEST METHOD THROUGH THE REGULAR ASTM PROCESS.

- CONCERNS:
  - EXPORT CONTROL REGULATIONS

APPENDIX 6

MIL HANDBOOK 17

P. Doyle

MIL-HDBK-17

COMPOSITE MATERIALS

FOR

AIRCRAFT AND AEROSPACE

APPLICATIONS

WHAT IS MIL-HDBK-17?

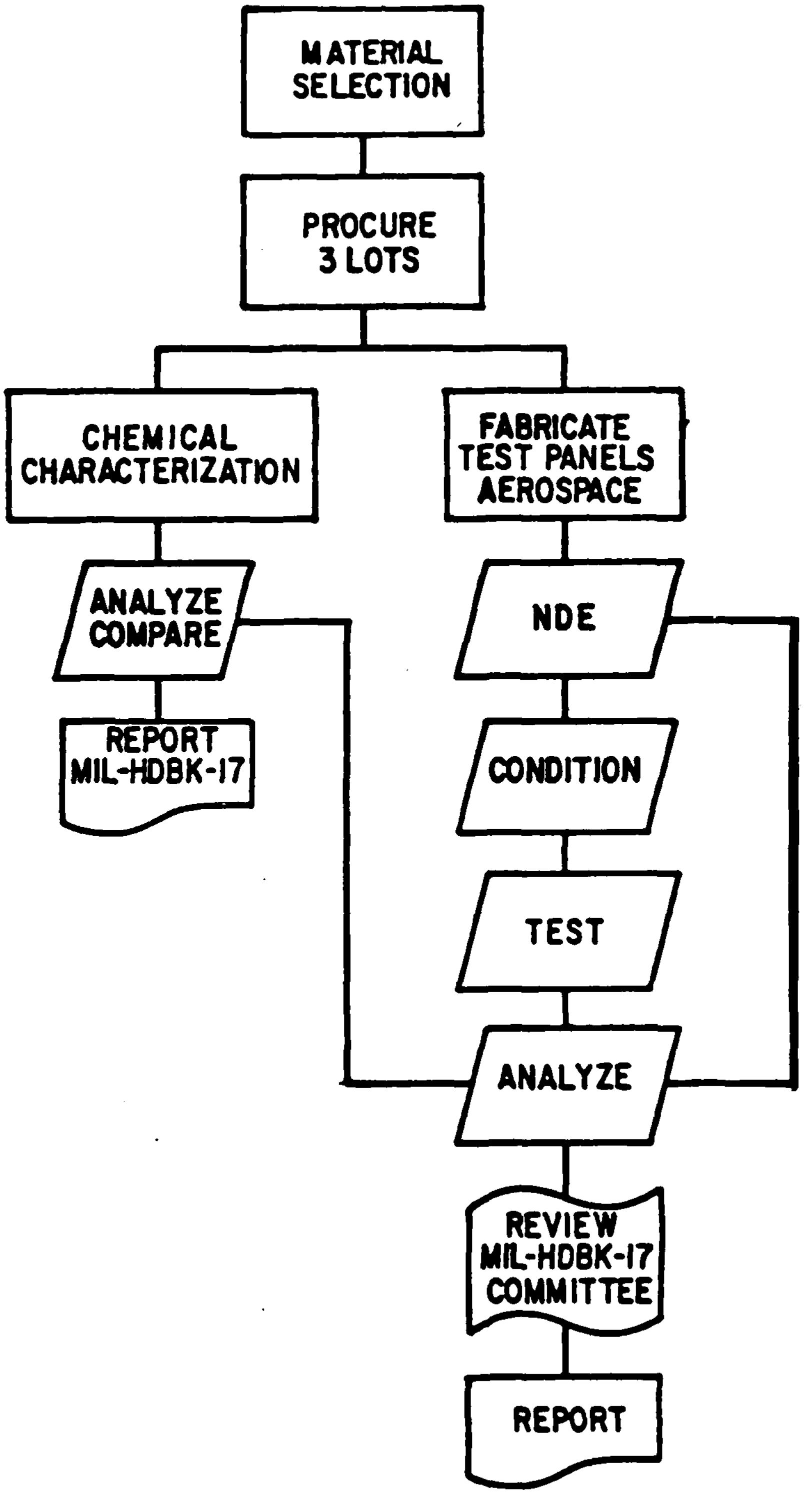
- REFERENCE DOCUMENT FOR RESIN MATRIX COMPOSITE MATERIAL.
- PRESENTS DATA ON A STANDARDIZED BASIS.
- ESTABLISHED MATERIAL ACCEPTANCE GUIDELINES.
- ACCEPTABLE TO DOD, FAA, NASA.

HISTORY OF MIL-HDBK-17

- EARLY 1960s - DOCUMENT COMPILED BY FOREST PRODUCTS LABORATORY, AIR FORCE PREPARING ACTIVITY
- MID 1960s - AIR FORCE PREPARING ACTIVITY, PLASTEC REPLACES FPL
- EARLY 1970s - REVISED EDITION PUBLISHED BY PLASTEC - EMPHASIZES FIBERGLASS REINFORCED PLASTICS
- MID 1970s - AIR FORCE EMPHASIZES DESIGN GUIDE FOR ADVANCED COMPOSITES (B&G REINFORCING FIBERS), MIL-HDBK-17 NOT UPDATED
- LATE 1977 - ARMY (AMMRC) ASSUMES PREPARING ACTIVITY

RECENT EVENTS

DATE	EVENT	RESULTS
Apr 78	1st MEETING OF GOVERNMENT REPRESENTATIVES	ORGANIZING & GENERAL ORIENTATION, ESTABLISHED OBJECTIVES, TITLE & MATERIALS
Jun 78	2nd MEETING OF GOVERNMENT REPRESENTATIVES	SOLIDIFIED OBJECTIVES, ESTABLISHED APPROXIMATE FUNDING REQUIREMENTS, AGENDA FOR GOV'T/INDUSTRY MEETING.
Jun 78	1st MEETING OF GOVERNMENT AND INDUSTRY REPRESENTATIVES	GENERAL ORIENTATION FOR INDUSTRY PERSONNEL, DISCUSSED OBJECTIVES, RECEIVED INDUSTRY IDEAS, INDUSTRY ENTHUSIASTIC ABOUT MIL-HDBK-17, ESTABLISHED NEED FOR QUESTIONNAIRE.
Aug 78	QUESTIONNAIRE SENT TO INDUSTRY	RESPONSE TO PRELIMINARY QUESTIONNAIRE IS GOOD -- RESULTS WILL BE MADE AVAILABLE AT UPCOMING MEETINGS.
Oct 78	3rd MEETING OF GOVERNMENT REPRESENTATIVES	QUESTIONNAIRE EVLAUATED AND ON-SITE VISITS PLANNED
Oct 78	2nd MEETING OF GOVERNMENT AND INDUSTRY [illegible]	QUESTIONNAIRE EVALUATED AND ON-SITE [illegible]


MATERIAL SELECTION
PROCURE 3 LOTS
CHEMICAL CHARACTERIZATION
FABRICATE TEST PANELS AEROSPACE
ANALYZE COMPARE
NDE
REPORT MIL-HDBK-17
CONDITION
TEST
ANALYZE
REVIEW MIL-HDBK-17 COMMITTEE
REPORT

	FY83	FY84	FY85	FY86	FY87	FY88	FY89
FUNDING	200	250	300	350	400	400	400

GOVERNMENT INTERFACE FY83-85

AMMRC
- ORGANIC MATERIALS LABORATORY
- METALS & CERAMICS LABORATORY
- MECHANICS & STRUCTURAL INTEGRITY LA[redacted]

AVRADCOM
NAVAL AIR SYSTEMS COMMAND
NASA
AFWAL
FAA
ARRADCOM
MICOM

PRIVATE INDUSTRY INTERFACE FY83-85

BEECH
BELL
BOEING AIRPLANE
BOEING VERTOL
CIBA-GIEGY
CONVAIR
GRUMMAN
GULFSTREAM AMERICAN
HERCULES
HUGHES
LEAR FAN
LOCKHEED
MARTIN MARIETTA
MCDONNELL DOUGLAS
NORTHROP
SIKORSKY
SOCIETY OF MANUFACTUR[redacted]
VOUGHT

MEETINGS

ANNUALLY, APPROXIMATELY 109 REPRESENTATIVES INVITE[redacted] WITH APPROXIMATELY 60 ATTENDEES.

AS OF NOVEMBER 83 WE WILL HAVE SEMI-ANNUAL MEETING[redacted]

<u>MIL-HDBK-17 TESTING</u>

PHASE I	Compression	ASTM D 3410
	Tension	ASTM D 3039
	Short Beam Shear	ASTM D 2344 •
PHASE II	Bolt Bearing	New Test Proposal (replacing ASTM [illegible]
	Shear	ASTM D 3518

• For initial material evaluation only

AGENDA ITEMS

- 81-1 GLASS MULTI-SITE DATA
- 81-2 PHASE I KEVLAR (C)
- 81-3 STATISTICAL ANALYSIS
- 82-1 GLASS DATA PHASE II
- 32-1 KEVLAR PHASE II (C)
- 82-3 AS4/3501-6 CARBON PHASE I
- 82-4 AS4/3501-6 CARBON PHASE II
- 82-5 T300/934 CARBON PHASE I
- 82-6 T300/934 CARBON PHASE II
- 83-1 & 2 BATCH TO BATCH VARIATION
- 83-3 & 4 TENSILE AND COMPRESSION NORMALIZATION
- 83-5 JOINTS WORKING GROUP
- 83-6 NEW SYSTEMS FOR EVALUATION
- 83-7 TEST CONDITIONS (C)
- 83-8 FILAMENT WIND WORKING GROUP
- 84-1 STATISTICAL ANALYSIS COMMITTEE
- 84-2 MATERIALS WORKING GROUP (REPLACES 83-6)
- 84-3 TESTING CHAPTER
- 84-4 INTRODUCTORY CHAPTER
- 84-5 SHEAR TEST EVALUATION COORDINATION GROUP
- 84-6 CHEMICAL CHARACTERIZATION CHAPTER
- 84-7 GUIDELINES CHAPTER
- 84-8 DEFINITIONS AND TERMINOLOGY

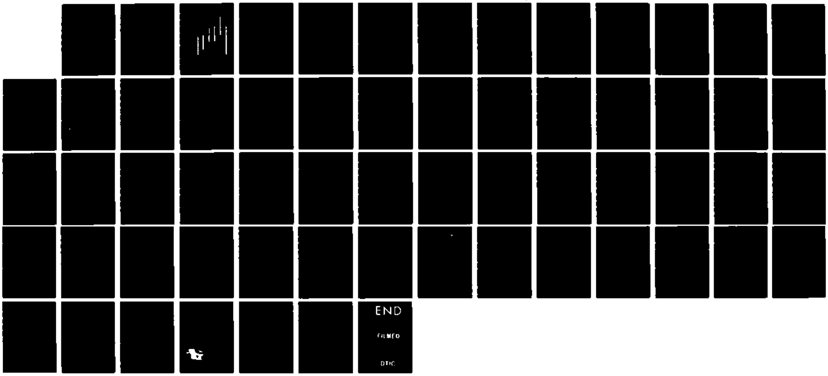
IMMEDIATE PROBLEM AREAS

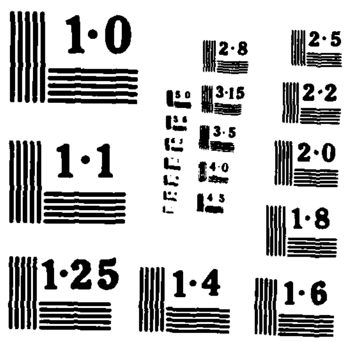
- NO GUIDELINES
- TEST METHODS
  - SHEAR
  - COMPRESSION
  - NORMALIZATION
- FEEDBACK (DATA, TEST METHODS, ETC.)
- STATISTICAL ANALYSIS
- WORK FASTER
  - NEW MATERIAL
  - REVISION

WORKING GROUPS

- GUIDELINES
- JOINTS TESTS
- FILAMENT WINDING
- MATERIAL SELECTION
- STATISTICAL ANALYSIS

AD-A157 903 MINUTES OF WORKSHOP ON COMPOSITE MATERIALS TEST METHODS 2/2
HELD AT THE INSTI..(U) INSTITUTE FOR DEFENSE ANALYSES
ALEXANDRIA VA S L CHANNON APR 85 IDA-M-81
UNCLASSIFIED IDA/HQ-85-29831 MDA903-84-C-0031 F/G 11/4 NL



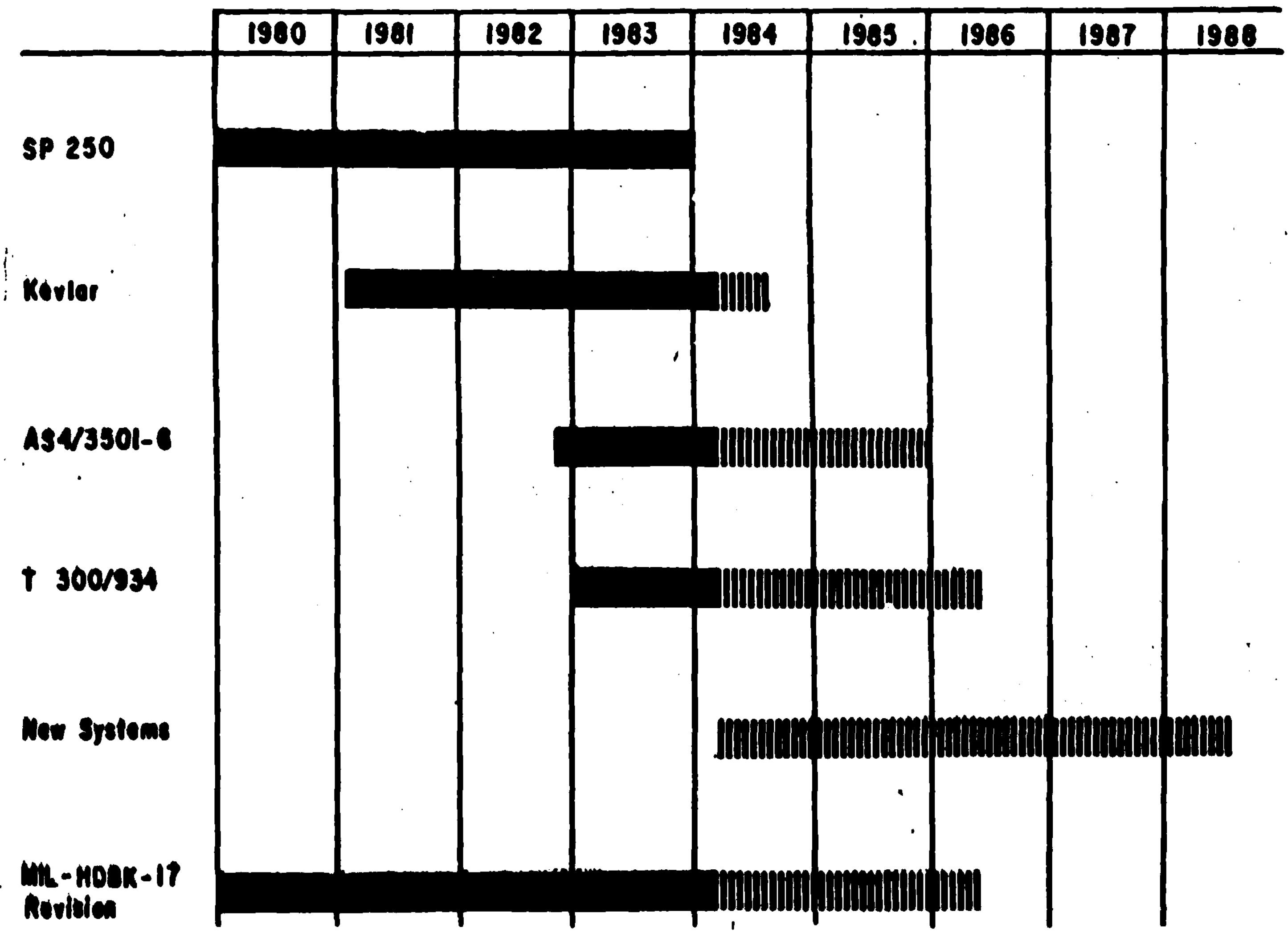


NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

NEXT MEETING

- STATISTICS SECTION COMPLETE
- LAMINA CHARACTERIZATION FOR REVIEW
- SCOPE OF DOCUMENT FOR REVIEW
- CHAPTERS 4 AND 5 PUT IN HANDBOOK FORMAT
- ROUGH DRAFT OF REVISION
- CHEMICAL CHARACTERIZATION SECTION COMPLETE

MIL-HDBK-17 REVISION SCHEDULE
Figure I.



APPENDIX 7

MIL STD 1944

F. Traceski

IDA Meeting Feb. 27, 1985

I believe that the DOD has the framework which is necessary to enhance composites standardization. This framework is the Defense Standardization and Specification Program (DSSP) and it takes the form of specifications, standards, handbooks and related standardization projects. The DSSP is comprised of various standardization policies and directives:

Defense Standardization and Specification Program

1. DoD 4120.3-M - Defense Standardization Manual
2. Military Standard 961A - Specifications
3. Military Standard 962A - Standards and Handbooks
4. SD-1 - Standardization Activities
5. SD-4 - Standardization Projects
6. SD-6 - Qualification
7. SD-8 - Overview of DSSP
8. SD-9 - Nongovernment Standards Bodies
9. OMB Circular A-119 - Voluntary Standards
10. DoDI 4120.20 - Nongovernment Standards
11. DODISS - Standardization Documents
12. Army Regulations

Examples of composites standardization projects managed by AMMRC include: MIL-HDBK-17, MIL-STD-1944 and MIL-G-46187

Having participated in the DSSP for nearly six years, I do not want to see another major program initiative outside of the DSSP which duplicates what we already have in place. I would like to see more implementation within the framework which has already been established.

Frank Traceski

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APPENDIX 8

NASA/AIRCRAFT INDUSTRY STANDARD

J. G. Davis

NASA/AIRCRAFT INDUSTRY STANDARD SPECIFICATION FOR GRAPHITE FIBER/TOUGHENED RESIN COMPOSITE MATERIAL

I.D.A. Workshop on Composite Materials
Test Method Development & Standardization
February 27, 1985
Alexandria, Va.

DR. JOHN G. DAVIS
CHIEF ENGINEER
ACEE, COMPOSITES
NASA
LANGLEY RESEARCH CENTER

STANDARD SPECIFICATION FOR GRAPHITE FIBER/TOUGHENED RESIN COMPOSITE MATERIALS

Objective

DEVELOP STANDARD SPECIFICATION FOR USE THROUGHOUT AIRFRAME INDUSTRY TO PROCURE COMPOSITE PREPREG

Scope

ESTABLISH REQUIREMENTS FOR PREPREG CONSISTING OF

- GRAPHITE FIBERS:

  1.5 PERCENT STRAIN TO FAILURE MINIMUM

- RESIN MATRIX:

  TOUGHENED THERMOSET POLYMER
  AUTOCLAVE CURE: 350° F MAX, 100 PSI MAX
  LAMINATE SERVICE TEMPERATURE: - 65° F TO 200° F

STANDARD SPECIFICATION

Key Features

Qualification

DEMONSTRATE THAT MATERIAL MEETS ALL CRITICAL REQUIREMENTS
3 BATCHES ~ 250 TEST ~ 85 POUNDS OF PREPREG

Acceptance

VERIFY THAT MATERIAL MEETS SELECTED REQUIREMENTS
EACH LOT ~ 60 TEST ~ 15 POUNDS OF PREPREG

Requirements

- FIBER PROPERTIES
- PREPREG PROPERTIES
- LAMINATE MECHANICAL PROPERTIES
- LAMINATE PROCESSING

Test Methods

- SPECIFIED FOR EACH REQUIREMENT

BACKGROUND AND APPROACH

- PARTICIPANTS - BOEING, DOUGLAS, LOCKHEED, NASA
- WORKSHOPS - APRIL 83, MAY 83, SEPTEMBER 83
- TASK GROUPS TO ESTABLISHED REQUIREMENTS
    - PREPREG REQUIREMENTS
    - LAMINATE REQUIREMENTS
- ESTABLISH SCOPE, CONTENT, FORMAT, TARGET VALUES AND TEST METHODS
- FIRST DRAFT OF SPECIFICATION CIRCULATED FOR REVIEW - JAN 84
- REVISED DRAFT SUBMITTED FOR FINAL REVIEW - JULY 84
- PUBLISH SPECIFICATION AS NASA REFERENCE PUBLICATION - MAR 85

STANDARD SPECIFICATION

Advantages to Prepreg Users

- HIGH/UNIFORM QUALITY
- ENHANCED AVAILABILITY/MULTIPLE SOURCES
- LOWER COSTS

Advantages to Prepreg Suppliers

- UNIFORM REQUIREMENTS FOR
  - FORMULATION
  - QUALITY CONTROL
  - TESTING
  - PROCESSING
  - QUALIFICATION
- IMPROVED MARKET OPPORTUNITIES FOR ALL SUPPLIERS

GRAPHITE FIBER REQUIREMENTS

PROPERTY	UNIT	VALUE
ULTIMATE TENSILE STRENGTH	PSI	520,000 MIN.
TENSILE MODULUS	PSI 10^6	33 - 37
ELONGATION AT FAILURE	PERCENT	1.5 MIN.
DENSITY	g/cm^3	1.70 - 1.83
WEIGHT/UNIT LENGTH	g/m	
GRADE 3000		0.18 MIN.
GRADE 6000		0.36 MIN.
GRADE 12000		0.72 MIN.
SIZING *	PERCENT	0.0 - 1.6
TWIST	TURNS PER INCH	0.0 - 0.8

* THE PREPREG SUPPLIER SHALL PROVIDE HPLC CHROMATOGRAM OF FIBER SIZING EXTRACT FROM EACH YARN LOT

PREPREG REQUIREMENTS

PROPERTY	REQUIREMENT	TEST METHOD (PARAGRAPH)	QUALIFICATION REQUIREMENT	ACCEPTANCE REQUIREMENT
RESIN CONTENT	35±2 PERCENT BY WEIGHT	A. 2	VERIFY QUALIFICATION REQUIREMENTS AS SPECIFIED IN SECTION 5.2	TEST EACH ROLL (PAR 5.3.3.1)
GRAPHITE FIBER AREAL WEIGHT	145±5 g/m^2	A. 3		TEST EACH ROLL (PAR 5.3.3.1)
VOLATILE CONTENT	≤ 0.5-PERCENT BY WEIGHT	A. 4		TEST AS SPECIFIED IN PAR 5.3.3.3
TACK	DEFINED IN REQUIREMENT A.5.6.	A. 5		
VISCOSITY PROFILE	TEST AND REPORT	A. 6		
CHEMICAL CHARACTERIZATION	TEST AND REPORT HPLC	A. 7		TEST ONE ROLL OF EACH LOT (PAR 5.3.3.2)
STORAGE LIFE AT 10°F MAXIMUM TEMP	SUPPLIER GUARANTEE MEET ALL SPECIFICATION REQUIREMENTS AFTER 6-MONTH STORAGE	A. 8		TEST AS SPECIFIED IN PAR 5.3.3.3
HANDLING LIFE	AFTER 10 DAYS AT 80° F, PASS TACK TEST	A .9.1		
PROCESSING LIFE	CURE LAMINATE AFTER PREPREG EXPOSED 30 - DAYS AT 80°F MAX, AND PASS REQUIREMENTS OF PARAGRAPHS B.2 and B.3	A .9.2		

LAMINATE MECHANICAL PROPERTY REQUIREMENTS

TEST	PLY ORIENTATION	SPECIMEN CONFIGURATION	REQUIRED DATA	TEST TEMPERATURE	VALUE	TEST REPLICATES/BATCH (1) QUALIFICATION	TEST REPLICATES/BATCH (2) ACCEPTANCE	TEST METHOD (PARAGRAPH)
TENSION	$[0]_8$	0.5 X 9 IN. TAB ENDS	STRENGTH	-100 °F	270 KSI	3		B.5
				RT	270	5	3	
			MODULUS	-100	18 MSI	3		B.5
				RT	18	3		
TENSION	$[\pm45]_{3S}$	1.0 X 11 IN. TAB ENDS	STRENGTH	RT	35 KSI	5		B.5
				200	35	3		
			SHEAR MODULUS	RT	4.5 MSI	3		B.11
				200	4.5 MSI	3		
COMPRESSION	$[0]_8$	0.5 X 3.15 IN. TAB ENDS	STRENGTH	-100	200 KSI	3		B.6
				RT	200	5	3	
				200	180	5	3	
				200 WET (3)	160	3		
			MODULUS	-100	18 MSI	3		B.6
				RT	18	3		
				200	18	3		
OPEN HOLE TENSION	$[45/0/-45/90]_{2S}$	1.5 X 12 IN. .25 DIA HOLE	STRENGTH	-100	50 KSI	3		B.8
				RT	50	3		
OPEN HOLE COMPRESSION	$[45/0/-45/90]_{2S}$	1.5 X 10 IN. .25 DIA HOLE	STRENGTH	RT	33 KSI	3		B.9
				200	30	3		
				200 WET (3)	26	3		
COMPRESSION AFTER IMPACT	$[45/0/-45/90]_{6S}$	7 X 12.5 IN.	STRENGTH	RT 20 FT-LB IMPACT	30 KSI	3		B.10
COMPRESSION INTERLAMINAR SHEAR	$[45/0/-45/90]_{6S}$	0.5 X 3.15 IN.	STRENGTH	RT	10 KSI	3	3	B.7
				200	8	3		
EDGE DELAMINATION	$[(\pm30)_2/90/90]_S$	1.5 X 10 IN.	INTERLAMINAR FRACTURE TOUGHNESS	RT	1.0 IN-LB/IN^2	3		B.12

(1) ALL TESTS INDICATED IN THIS TABLE ARE REQUIRED FOR PREPRODUCTION QUALIFICATION. FOR PREPRODUCTION QUALIFICATION REQUIREMENTS SEE SECTIONS - 4.1, 5.2

(2) TESTS INDICATED IN THIS COLUMN ARE REQUIRED FOR PRODUCTION ACCEPTANCE. FOR PRODUCTION ACCEPTANCE REQUIREMENTS SEE SECTIONS - 4.2, 5.3

(3) WET CONDITIONING: SOAK SPECIMENS IN 160°F DEMINERALIZED WATER TO 70-PERCENT SATURATION MINIMUM

LAMINATE PROCESSING REQUIREMENTS

TEST PANEL 24 In X 26 In X 48 PLIES QUASI -ISOTROPIC FABRICATED AS SPECIFIED IN SECTION - A.II

PROPERTY	REQUIREMENT	TEST METHOD	QUALIFICATION REQUIREMENT	ACCEPTANCE REQUIREMENT
LAMINATE THICKNESS PER PLY	.0054 - .0056 IN	B.4.2	AS SPECIFIED IN SECTION 5.2	NONE
RESIN CONTENT	29-35 PERCENT BY WT	B.2		TEST PER 5.3.3.4
VOID CONTENT	2 PERCENT MAXIMUM	B.3		TEST PER 5.3.3.4
DENSITY	1.53 - 1.62 g/cm^3	B.3.2		NONE

DEFECTS	LIMITS	TEST METHOD	QUALIFICATION REQUIREMENTS	ACCEPTANCE REQUIREMENTS
SINGLE VOID AREA	0.25 IN^2 MAX	A.II.4	SPECIFIED IN SECTION 5.2	AS SPECIFIED IN SECTION 5.3.3.4
TOTAL ACCUMULATED VOID AREA	1.00 IN^2 IN ANY 1-FT^2			
SINGLE POROUS AREA	1.00 IN^2 MAXIMUM			
TOTAL ACCUMULATED POROUS AREA	4.00 IN^2 IN ANY 1 FT^2			
DISTANCE BETWEEN VOIDS	4.00 IN MINIMUM			
DEFECT DISTANCE TO FINISHED EDGE	1.00 IN MINIMUM			

STANDARD SPECIFICATION

Content / Organization

1. SCOPE

2. CLASSIFICATION

3. DOCUMENTS AND DEFINITION

4. REQUIREMENTS
4.1 QUALIFICATION APPROVAL
4.2 ACCEPTANCE APPROVAL
4.3 COMPONENT REQUIREMENTS
4.3.1 FIBER REQUIREMENTS
4.3.2 RESIN REQUIREMENTS
4.3.3 PREPREG REQUIREMENTS
4.3.4 LAMINATE REQUIREMENTS

5. QUALITY ASSURANCE PROVISIONS
5.1 SUPPLIER RESPONSIBILITIES
5.2 QUALIFICATION
5.3 ACCEPTANCE

6. PREPARATION FOR DELIVERY

STANDARD SPECIFICATION

Content / Organization

Appendices – Test Methods

APPENDIX A - TEST METHODS
FOR UNCURED PREPREG PROPERTIES

A.1 SAMPLING PROCEDURE
A.2 WET RESIN CONTENT
A.3 CARBON FIBER AREAL WEIGHT
A.4 VOLATILE CONTENT
A.5 TACK
A.6 VISCOSITY PROFILE
A.7 HPLC CHARACTERIZATION
A.8 STORAGE LIFE
A.9 OUT TIME
A.10 STANDARD CURE CYCLE
A.11 PROCESSABILITY TEST PANEL

APPENDIX B - TEST METHODS
FOR CURED LAMINATE PROPERTIES

B.1 GENERAL
B.2 RESIN CONTENT
B.3 VOID CONTENT
B.4 FIBER VOLUME AND PLY THICKNESS
B.5 TENSILE TEST
B.6 COMPRESSION STRENGTH AND MODULUS
B.7 COMPRESSION INTERLAMINAR SHEAR
B.8 OPEN HOLE TENSION
B.9 OPEN HOLE COMPRESSION
B.10 COMPRESSION AFTER IMPACT TEST
B.11 LONGITUDINAL SHEAR MODULUS
B.12 EDGE DELAMINATION TENSION TEST

APPENDIX C - ACCEPTANCE/REJECTION CRITERIA

C.1 ACCEPTANCE
C.2 REJECTION

APPENDIX 9

REQUIREMENTS FOR TEST METHOD STANDARDIZATION

P. R. DiGiovanni

REQUIREMENTS FOR TEST METHOD STANDARDIZATION FOR COMPOSITE MATERIALS

DOD/IDA WORKSHOP ON TEST METHODS FOR COMPOSITE MATERIALS - DEVELOPMENT AND STANDARDIZATION

PETER R. DIGIOVANNI

RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION
BEDFORD, MA

27 FEBRUARY 1985

- <u>PROBLEMS</u>

  - FIBER REINFORCED COMPOSITE ARE HIGHLY ANISOTROPIC
    - ISOTROPIC THEORIES OF ELASTICITY/PLASTICITY NOT VALID
    - CLASSICAL FAILURE MECHANISMS NOT EXPERIENCED BY COMPOSITES
    - NUMBER OF INDEPENDENT MATERIAL PARAMETERS GREATER
  - CLASSICAL EXPERIMENTAL PROCEDURES MOST OFTEN INVALID
    - BASED ON FICTITIOUS ISOTROPIC MATERIAL BEHAVIOR
  - TEST DATA OFTEN GATHERED BY "UNINITIATED" ENGINEERS AND TECHNICIANS
    - DATA OFTEN MISINTERPRETED
    - DESIGNERS USE MISINTERPRETED DATA
    - STRUCTURES OVERDESIGNED, FAIL, OR ADV. MATERIALS USE AVOIDED
  - ASTM STANDARDS OFTEN REFERENCED TO LEND CREDIBILITY TO INVALID DATA
  - GENERALLY SUSPECTED THAT ASTM STANDARDS DEVIATED DURING TESTS

PROBLEMS (CONT'D)

- ASTM COMMITTEE D30 "ON HIGH MODULUS FIBERS AND COMPOSITES" SHOULD BE MAJOR TECHNICAL SOURCE FOR COMPOSITE COMMUNITY
  - APPROPRIATE MEMBERS TO PROVIDE TECHNICAL EXPERTISE ON COMPOSITE TESTING
  - D30 OFTEN BYPASSED RESULTING IN NUMEROUS AND QUESTIONABLE TEST PROCEDURES USED TO ACQUIRE MATERIAL DATA/PROPERTIES
- METAL MATRIX AND HIGH TEMPERATURE TEST PROCEDURES NOT RECEIVING APPROPRIATE ATTENTION
- PROPERTIES PROCESS DEPENDENT

- **ACTIONS REQUIRED FOR PROBELM SOLUTION**
  - ASTM ACTIVITY MUST BE INCREASED
  - MANY ASTM COMPOSITE STANDARDS REQUIRE DETAILED REVIEW, SUBSTANTIATION, MODIFICATION
  - "BOOT LEGGING" ROUND ROBINS INEFFECTIVE AND COMPOUND PROBLEMS
    - DOD MUST SUPPORT RIGOROUS ASTM ROUND ROBIN TESTS
  - FORMAL ROUND ROBIN TEST REPORTS SHOULD BE DISTRIBUTED TO WIDER COMMUNITY
    - PUBLISHED IN OPEN LITERATURE

      EX: COMPOSITE TECHNOLOGY REVIEW
  - GOVERNMENT AGENCY REPORTS OFTEN PRESENT RESULTS WITH NO DISCUSSION OF DETAILED TEST PROCEDURES
    - CANNOT EVALUATE DATA VALIDITY

- SPECIFIC RECOMMENDATIONS
  - PROPOSE ONE ASTM ROUND ROBIN TEST FOR DOD SUPPORT ASAP
    - TENSION: DISCONTINUOUSLY REINFORCED ALUMINUM FOR RT AND HIGH TEMPERATURE
    - COST PROGRAM AT WORKSHOP
    - SUBMIT PROPOSAL TO DETERMINE DOD RESPONSE
    - LEARN FROM THIS EXPERIENCE TYPICAL TESTING COSTS, REPORTING LOGISTICS, TOTAL TIME REQUIRED FROM START TO STANDARDS ACCEPTANCE
    - UTILIZE AS BASELINE FOR OTHER STANDARDS DEVELOPMENT

- NEW/MODIFIED STANDARDS REQUIREMENT
  - INTERLAMINAR SHEAR
  - IN-PLANE SHEAR
  - FLEXURE
  - TENSION
  - FATIGUE
  - MODULI MEASUREMENTS
  - HIGH TEMPERATURE MEASUREMENTS
  - MUST INCLUDE LAMINA ORIENTATION EFFECTS

- DEVELOP FIXTURES/PROCEDURES THAT ARE FEASIBLE FOR USE BY MODERATELY COMPETENT TEST FACILITIES
  - SPECIALIZED EXPENSIVE TESTS OFTEN PERFORMED BY GRADUATE STUDENTS OFTEN NOT FEASIBLE FOR INDUSTRY
  - MUST DETERMINE ACCURACY REQUIREMENTS (OVER SPECIFICATION LEADS TO NON-COMPLIANCE AND UNNECESSARY COSTS)

- <u>DATA REQUIREMENTS</u>
  - STATISTICAL
  - A, B ALLOWABLES
  - ARITHMETIC AVERAGE
    - ARE A ALLOWABLE ALWAYS NECESSARY? WHY?
    - DESIGNERS OFTEN NEED REASONABLE DATA FOR CONCEPT EVALUATION

- DOCUMENTATION
  - MUST BE COMPLETE
  - PREPARE AS IF JOURNAL ARTICLE
  - AVOID PHRASES "CAPACITANCE METHOD USED"
    - DESCRIBE DEVICE, MANUFACTURER, COST
    - SET UP TIME
    - REPEATIBILITY
    - ACCURACY
    - TIME TO CONDUCT TEST
    - NO. OF TECHNICIANS/ENGINEERS REQUIRED
    - DATA MANAGEMENT
    - SPECIAL NEEDS
  - LET THE READER UNDERSTAND TOTAL TEST REQUIREMENTS AND OPTIONS

- CONCLUSIONS
  - NEED EXISTS FOR COMPOSITE TESTING STANDARDS DEVELOPMENT - PRESENTLY FRAGMENTED
  - ASTM MOST APPROPRIATE ORIGINATOR OF STANDARDS
  - DoD SUPPORT REQUIRED FOR PROPER COMPOSITE STANDARDS DEVELOPMENT
  - ASTM FOLLOW UP REQUIRED TO INSURE PROPER STANDARDS UTILIZATION
  - PROPOSE ONE MMC TEST STANDARD (TENSION) FOR BASELINE AND EVALUATION OF DoD/ASTM COOPERATIVE EFFORT
  - COMPOSITE TESTING UNDERSTANDING, INTERPRETATION, AND CONDUCT MORE DEMANDING THAN ISOTROPIC METALS
  - HIGH TEMPERATURE TEST PROCEDURES REQUIRE IMMEDIATE RESPONSE

APPENDIX 10

JANNAF TESTING AND INSPECTION

A. Munjal

JANNAF

COMPOSITE MOTOR CASE SUBCOMMITTEE

TESTING & INSPECTION PANEL

SURVEY: TEST METHODS FOR COMPOSITE CASES

NAME: ______________________

ORGANIZATION/ADDRESS: ______________________

____

____

TELEPHONE NUMBER: ______________________

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PHYSICAL PROPERTY TESTS

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
1. Density of High Modulus Fibers	D-3800	6-in long fiber strands	Density of fiber			Method applicable to continuous and discontinuous fibers	
2. Density of plastics	D-792	Specimens 1 to 50 grams	Density of plastic				
3. Density of a laminate	HAD	Physical properties specimen	Density of laminate			Specimen surface should be free of any foreign material	
4 Resin Gel time	D-2471	Resin (15 ml.)	gel time, T_{max}				
5. Resin content in prepreg	D-3529	80mm x 80 mm x thickness	% of Resin Solids Content			Uses Methyl Ethyl Ketone (MEK) and dimethyl formamide (DMF) as digestants	
6. Resin content in laminates	HAD	Physical property specimen	% resin content in laminates			Uses sulfuric acid (H_2SO_4) and HNO_3 as digestants	
7. Volatiles content of carbon epoxy prepreg	D-3530	130 x 130 mm x thickness	volatile content in prepreg			Uses two temperatures: 121 ± 3°C, 177 ± 3°C, for 10 ± 0.5 min.	
8. Fiber content in composites	D-3171	0.30 g min. weight	fiber wt %, fiber vol. %			Uses 3 digestions solutions for matrix	
9. Fiber content in composites	HAD	Physical property specimen	fiber content, wt %				

(continued)

PHYSICAL PROPERTY TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
10 Fiber volume in laminates	HAD	Physical property specimen	fiber volume %			Needs $\sigma_{laminate}$, σ_{resin}, σ_{fiber}, resin content, fiber content	
11 Void content of reinforced plastics	D-2734	Minimum volume of 2 cm^3	void content %			Needs σ_{resin}, σ_{fiber}, resin content, fiber content	
12. Void content	HAD	Physical property specimen 1 g < weight < 2.5g	void content %			$\sigma_{laminate}$, σ_{resin}, σ_{fiber}	
13. Kinematic viscosity of liquids	D-445	liquid	Kinematic & dynamic viscosity				
14. Viscosity of non-Newtonian materials	D-2196	Non-Newtonian material	Apparent viscosity & shear thinning				
15. Deflection temperature of plastic under flexural load	D-648	See test specimen in D-648	deformation temperature			Also known as heat distortion temperature	
16. Steady state thermal transmission	C-177	See test specimens	thermal resistance, thermal conductance			Also known as thermal conductivity test	

(continued)

PHYSICAL PROPERTY TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
17. Coeff. of linear thermal expansion of plastics	D-696	50 mm < length < 125 mm	coeff. of linear thermal expansion (α)				
18. Transition temp. of polymers by thermal analysis	D-3418	5 mg specimen	Glass transition temperature T_m			Also known as DEC (Differential Scanning Calorimetry) and DTA (Differential Thermal Analysis)	
19. Water absorption of plastics	D-570	disk 2 in diam., 1/8 in thick	absorption of water by immersed plastics			Also known as moisture absorption test	
20. Water using Karl Fischer Reagent	E-203		water content				
21. Specific heat of Liquids & Solids	D-2766	1 x 1 x 2 in	heat capacity of liquids & solids				
22. Ignition loss of cured reinforced resins	D-2584	5g., 2.5 x 2.5 cms thickness	Ignition loss; resin content			Ignition loss = resin content for glass reinforced materials	
23. Resin flow of carbon fiber-epoxy prepreg	D-3531	2 ply, 2 in square specimen	resin flow under temperature & pressure				

(continued)

PHYSICAL PROPERTY TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
24. Resin content of prepregs	C-613	10 ≤ weight ≤ 15 g	Volatile content, wet resin content, dry content			Soxhlet extraction used	
25. Chemical analysis of graphite	C-560	crushed & ground graphite	parts per million of silicon, iron, calcium, Al, titanium, vanadium, boron				
26. Moisture in graphite	C-562	crushed & ground graphite	% of moisture in graphite			Not good for graphite exposed to liquid water, only good for moisture absorption from atmosphere	
27. Visual defects in glass reinforced plastic laminates (carbon fiber-epoxy)	D-2563	subscales and full scales	visual acceptance, levels of defects				
28. Gel time of prepreg	D-3532	6.3 mm^2	gel time of carbon fiber-epoxy of tape and sheet			Good for resin systems with high or low viscosity	
29. Viscosity using RV-1 Rotovisco	HAD	Physical properties specimen	viscosity in resin			Used for MX material screening series	
30. Viscosity using RV-2 Rotovisco	HAD	Physical properties specimen	viscosity in resin				

TENSION TESTS

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
1. Tensile properties of plastics	D-638	Dumbbell shaped *specimens	$E_1, E_2, \nu_{12}, \nu_{21}, \varepsilon_1, \varepsilon_2, \sigma_1, \sigma_2$			Not good for thin sheeting	
2. Tensile strength of tubular material by split disk	D-2290	Tubular ring-shaped specimen	$E_{11}, \sigma_{11}, \varepsilon_{11}, \nu_{11}$			Split disk goes inside the ring	
3. Tension testing of filament wound pressure vessels	D-2585	Small pressure vessels	σ_1, σ_2, E, ε			Assumes: matrix carries no load, density of fiber is known, there is sufficient netting analysis	
4. Tensile properties of fiber-resin composites	D-3039	Laminated tab (coupon)	$\sigma_{ult}, \varepsilon_{max}$, E, ν			Good for unidirectional 0, 90deg. Laminates of symmetric, orthotropic construction and cross-play fiber reinforced laminates	
5. Tensile properties of fiber-resin composites	D-3039 (Mod)	tubes	$\sigma_{ult}, \varepsilon_{max}$, Z, ν				
6. Tensile properties of glass fiber strands, yarns and rovings	D-2343	Fiber strands, yarns or roving 14 to 18 in. long	σ_1, σ, E				

(continued)

TENSION TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
7. Tensile properties of thin plastic sheeting	D-882	Strips of uniform width and thickness	breaking factor, σ_t, σ_{yield} E, ε			Up to 1.0mm thick	
8. Tensile properties of adhesive bonds	D-897	Tensile buttons	σ, E			Good for wood to wood, metal to metal	
9. Tensile bond tests	HAD	Buttons in sandwich form of composite & rubber	σ, E, ε				
10. Axial tensile test (for FWC)	HAD (FWC)	24 in long x 4.0 width x thickness	σ_{11}, ε_{11}, , E_{11}			Also known as Type I tensile. See diagram in test procedure in FWC program	
11. Axial tensile Modulus tests	HAD (FWC)	22.5 long x 2.5 in wide x thickness	$E_{axial\ tensile}$, σ_{at}, ε_{at}			Used for tag end tests in FWC	
12. Tension tests in 4-inch cylinders	HAD	Cylinders 4.0 in diam. x 3.5 in long x thickness	σ_{22}, ε_{22}, E_{22}				
13. Tensile tests on a flat unidirectional plate	HAD	Flat plate (prepreg) 20 in. x 20 in x 0 14-1.11 in thick	σ_{11}, ε_{11}, , E_{11}			Used in MX program	

(continued)

TENSION TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
14. Pressurized 4-inch cylinder in tension	U of U	4.0 in. diameter 16-18 in. long x thick.	$G_{\theta\theta}$, $Q_{\theta z}$, Q_{zz} σ_θ ε_θ E_θ, σ_z, ε_z, E_z			$Q_{\theta\theta} = \frac{E\theta\theta}{1-\nu_{\theta z}\nu_{z\theta}}$ = stiffness coeff.	
15. Chamber/ insulator bond	HAD	2 x 2 in button	σ, ε, E				
16. Tensile properties of continuous filament carbon and graphite yarns, strands, rovings, and tows	D-4018	a 10,000 filaments yarn, 13 in. long	σ_{ult}, E, ε				
17. Tensile properties of pultruded glass-fiber reinforced plastic rod	D-3916	rods 1/8 in. < diameter < 1 in.	$\sigma_{tensile}$, E, ε				

COMPRESSION TESTS

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
1. Compressive properties of rigid plastics	D-695	Coupons	$\sigma_{compressive}$, ε, σ_{yield}, E				
2. Compressive properties of unidirectional or crossply fiber-resin composites	D-3410 (Celanese) Type I	Flat coupons (unidirectional cross ply) 5.5 in. x 0.25 in.	σ_{ult}, ε, E, μ (Poisson's ratio) failure mode			Requires extreme precision in mounting the specimen in the fixture; unsupported test section	
3. Pressurized 4-inch cylinder in compression	U of U	4 in. diameter 12-14 inch long	$Q_{\theta\theta}$, $Q_{\theta z}$, Q_{zz} σ_θ ε_θ E_θ, σ_z, ε_z, E_z $v_{\theta z}$, $v_{z\theta}$			$Q_{\theta\theta} = \frac{E\theta\theta}{1-v_{\theta z}v_{z\theta}}$ = stiffness coeff.	
4. Illinois Inst of Technology and Research Institute (IITRI) Type I compression test	IITRI	Uniaxially loaded flat coupon same as ASTM D-3410	$\sigma_{1\ ult}$, $\sigma_{2\ ult}$, ε_1, ε_2, E_{11}, E_{22}, v_{12} v_{21}, E_θ			IITRI → very good overall, requires prolonged soak periods for elevated temp. testing due to mass of test fixture, careful specimen preparation	
5. National Bureau of Standards (NBS) Type I compression test	NBS	4.65 in. x 0.5 in. coupon	σ_1, ε, E, v			NBS → combines features of Celanese and IITRI	

(continued)

COMPRESSION TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
6. Northrop Type I compression test	Northrop	coupon (3 in. x 0.75 x 0.08-0.096)	$\sigma, \varepsilon, \nu, E$			Northrop method has a simpler test fixture than Celanese and IITRI	
7. Southwest Research Institute (SWRI) Type II compression test	SWRI	Coupon (8 in. x 1 in. x 0.18-0.188 in.)	$\sigma, \varepsilon, \nu, E$			SWRI longitudinal strain measurements may be erroneous for laminates with free-edge effect	
8. Lockheed Calif. Co. Type II compression	Lockheed	129.5 mm x 62.99 mm x 19.05 mm coupon	$\sigma, \varepsilon, \nu, E$			Lockheed: load transferred through shear rather than direct compression	
9. Sandwich edgewise compression test	Edgewise sandwich beam	Two composite coupons bonded to a honeycomb core	E, σ, ν			Edgewise: problem of premature and crushing load applied through self-aligning bearing blocks	
10. Sandwich beam in four-point bending	Four-point bend sandwich	Composite coupon, honeycomb core, metal sandwich	E, σ, ν			S.B. in 4-point: not recommended for Poisson's ratio measurements; can be used for tensile properties, expensive, but very good overall	

(continued)

COMPRESSION TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
11. Reusable sandwich beam in four-point bending	Reusable sandwich beam	12 in. x 0.5 in. coupon	E, σ, v			More economical than the sandwich beam, still has the Poisson's ratio error	
12. NARMCO test method 303	NARMCO					No test procedure or method available	
13. Texaco Experiment Inc. (TEI) bundle test	TEI					No test procedure or method available	
14. Royal Aircraft Establishment compression test	RAE		E, σ, v			No test procedure or method available	
15. Hydrostatic compressive strength of glass-reinforced plastic cylinders	D-2586	Filament wound cylinder	$\sigma_{compressive}$			Considered option test method by Wolstencraft et al.	

SHEAR TESTS

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
1. In plane shear-strain response of unidirectional reinforced plastics	D-3518	Coupons of ± 45° laminate	Shear strength, shear modulus			Deleterious influence of the tensile transverse stress upon ultimate shear strength	
2. Shear strength of plastic by punch tool	D-732	2-in. square, or 2 in. diameter disk, thickness = 0.005 in. - 0.5 in.	Shear strength				
3 In-plane shear strength of reinforced plastics	D-3846	3.13 x 0.5 x 0.1 to 0.260 in.	In plane shear			Compresive loads work better in brittle materials	
4 Apparent interlaminar shear strength of parallel fiber composites by short-beam method	D-2344	Short beam up to 0.25 in. thick	Shear strength			It can be used for hoop and axial directions in composites	
5. Off-axis tensile test	D-3039	Coupons	$\tau_{12}, \gamma_{12}, G_{12}$			Uses a rectangular three-element rosette gage. Consistent for any angle 0, 10° off axis is recommended	

(continued)

SHEAR TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIA-GRAM
6. Rail shear test	D-30 Committee (unpublished)	Coupon two-rail and three-rail	τ_{12}, γ_{12}, G_{12}			Two-rail and three-rail can be used	
7. Torsion method	Rod or tube torsion test	Solid rod, thin-walled cylinder	G_{12}, τ_{12}, γ_{12}				
8. Strength properties of adhesives in shear by tension loading (metal-metal)	D-1002	Metal tabs and adhesive				Compressive loads work better in brittle materials	
9. Axial inter-laminar shear		2 cubes 1.99 in. x 1.45 in. x thickness	τ_{max}, γ_{max}, G_{12}			Used in FWC at Hercules	
10. "Bow-Tie" rail shear test	Bow-Tie	Coupon	τ, γ, G_{12}			Developed by Boeing	
11. Iosipescu shear test	Iosipescu	Notched coupon thickness = 0.5 in.	τ, γ, G_{12}			It can be used in axial or transverse direction in composites	
12. Picture frame	Picture frame	Square sections	τ, γ, G_{12}			Usually it fails at the bonding of the frame to specimen. Need test method and procedure.	

(continued)

SHEAR TESTS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
13. Cross-sandwich beam	Cross-sandwich beam	Cross-shaped coupons with honeycomb material as filler	ι, γ, G_{12}			The center square of the cross is under test. Need test method and procedure	
14. Four-point ring twist test for determining the shear modulus of composites	Greszczuk STP 734	Circular rings	G_{12}			Good for characterizing materials at room, cryogenic, and elevated temperatures	
15. Douglas split ring test	Greszczuk two-point	Circular rings	G_{12}				

OTHERS

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
1 Plane-strain fracture toughness of metallic materials	E-399	Fatigue cracked specimens thickness > 0 063 in	Plane-strain fracture toughness K_{IC} strength ratio				
2. The width-tapered double cantilever beam for interlaminar fracture testing	WTDCB	Prepreg tapered coupons with aluminum pulling tabs	Mode I interlaminar fracture energy (G_{IC})			Good for delamination resistance and growth predictions	
3 Impact resistance of rigid plastic, sheeting or parts by means of a tup	D-3029	Plastic sheeting	Energy required to crack or break rigid plastic sheeting			Two tup sizes are used which will cause 50% of the specimens to fail	
4. Impact resistance of plastics and electrical insulating materials	D-256	Cantilever beams notched and unnotched	Impact strength			Uses a pendulum for impacting	
5. Notched bar impact testing of metallic materials	E-23	Simple beams notched and unnotched	Describes Charpy and Izod methods			Use striking edges and pendulums as impactors	

(continued)

OTHERS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNA-TION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIA-GRAM
6. Vinyl-coated glass yarns	D-3374	Glass yarns	Acceptance or rejection of lots of vinyl-coated glass yarns				
7. Glass fiber yarns	D-578	Glass yarns	Designate the types of glass fiber yarns available in the industry				
8. Conditioning plastics and electrical insulating materials for testing	D-618		Standardize humidity and temperature *conditions of* specimens prior to and during testing			Used for almost every test	
9. Load verification of testing machines	E-4		Calibration of testing machines				
10. Comparative extinguishing characteristics of solid plastics	D-3801	13 x 127 mm. specimens	Flaming time, heat and flame response, glowing time			Should not be used to appraise fire hazard or fire risk of materials	
11. Linear shrinkage of cured thermo-setting casting resins during cure	D-2566	Resin	Linear shrink-age in cm.				

(continued)

OTHERS (Cont'd)

TEST NAME	(ASTM #) METHOD DESIGNATION	TEST VEHICLE	OUTPUT PARAMETERS	MATERIAL A B C D E	APPLICATION OF RESULTS (see key) 1 2 3 4 5 6 7 8 9 10	COMMENTS	DIAGRAM
12. Tensile, compressive, and flexural creep and creep-rupture of plastics	D-2990	As in D-638, D-1822, D-695, D-790	Extension, compression, and deflection as a function of time				
13. Bearing strengths of plastics	D-953	See fig. in test method	Bearing strength			Good for rigid plastics in either sheet or molded form	
14. Peel resistance of adhesives (T-Peel Test)	D-1876	1-in. wide specimens cut from laminated panels	T-peel strength				
15. Creep properties of adhesives in shear by compression loading	D-2293	Same as D-1002 (lap shear)	Creep of specimen under compression				
16. Creep properties of adhesives in shear by tension loading	D-2294	Same as D-2293 and D-1002	Creep of specimen under tension			Method is applicable to a temperature range -55 to 280°C	

KEY

A	Resin
B	Fiber
C	Composite
D	Analog
E	Other

1	Screening
2	Design/Analysis Properties
3	Processing Effects
4	Environmental effects
5	Aging
6	Damage Tolerance
7	Statistical Data Base
8	Quality Control
9	Material Development
10	Other

APPENDIX 11

TEST METHODS FOR COMPOSITES

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TEST METHODS FOR CHARACTERIZATION OF FIBER REINFORCED COMPOSITES

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ABSTRACT

Because of their nonisotropic and inhomogeneous nature, the testing of composites is more extensive than that of metals and is still evolving. Sample preparation and test methods are not fully developed or standardized for the industry. Test data depend upon the test method, specimen design and the composite void content. The work reported in this paper is in the direction of standardizing test methods for the industry and reviews the present status of test methods for characterization of fiber reinforced composites. Test methods available for tension, compression and shear are summarized and advantages and disadvantages of each are discussed. Recommendations have been made as to which test methods are acceptable for determining design allowables and which test methods are suitable only for comparative purposes and quality control. Where available, test data obtained from different test methods and/or different specimen designs have been discussed.

"Key Words": Test Methods, Composite, Characterization, Standardization, Tension, Compression, Shear

INTRODUCTION

Composites offer advantages over metals in terms of lower weight, higher specific strength and modulus, higher fatigue resistance, better oxidation and corrosion resistance, and better control of thermal and electrical properties. For composites to be used efficiently, these must be characterized completely. Because of their inhomogeneous nature, the testing of the composites is more extensive than that of metals and is still evolving. Sample preparation and test methods are not fully developed or standardized for the industry. Test data depend upon the test method, specimen design and composite void content. Resin dominated properties like shear, compression and transverse tension are greatly affected by void content. In absence of standard test methods, the data reported by the individual companies cannot be used by the industry for accurate analysis or design allowables. This prohibits extensive use of the composites by individual companies without spending large amounts of money in characterization testing. Recently a significant amount of composite testing has been done in the industry to compare the various test methods (1-10). However, we are still far away from having standard test methods for the industry such that the test data obtained from different sources can be compared on a one to one basis. Efforts are being made by various agencies such as JANNAF, MIL-HDBK-17 and ASTM Committee on D-30 High Modulus Fiber to standardize the test methods.

This paper is in the direction of standardizing test methods for the industry and reviews the present status of the test methods for characterization of fiber-reinforced composites.

OBJECTIVES

- To review the present status of test methods for characterization of fiber reinforced composites.
- To summarize the test methods available for tension, compression and shear and discuss advantages and disadvantages of each.
- To recommend which test methods are suitable for determination of the design allowables and which are good just for quality control comparison purposes.
- Where available, discuss and compare test data obtained from different test methods or using different specimen designs.

SPECIMEN FABRICATION AND PREPARATION

Specimen design and fabrication should parallel that for the end product in order to obtain the most meaningful data. Where possible, a correlation factor should be established between the

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subscale and the large scale specimens or parts to account for the processing parameters. All mechanical data should be correlated with the specimen fiber volume, resin content, void content, density, glass transition temperature, etc. Though machining of glass and graphite composite specimens poses no problems, machining of Kevlar* specimens is not recommended by conventional methods using carbide blades or high speed carbide end mills. Because of the induced delaminations and fuzzing at the edges, laser machining may be required for Kevlar specimens. Machining of Kevlar specimens by a water jet cutting technique may be acceptable if there is no pickup of moisture during cutting and the specimen edges are clean and true.

Bonding of end tabs or strain gages generally does not give any problems with graphite, glass or regular Kevlar composites. However, composites using Kevlar 49 coated with release agents to give higher fiber pressure vessel performance (11) may give bonding problems. Generally the strain gage adhesive should be cured at test temperature. All finished specimens should be examined visually for any defects. Nondestructive inspection techniques can be included if quantitative data on the nature of the defects present in the specimens are needed.

TEST METHODS

PHYSICAL PROPERTY TESTING

Physical properties including fiber volume, resin content, void content and density should be determined on all representative composite specimens for correlation with the mechanical properties. All fiber dominated properties including longitudinal tensile strength and modulus are affected by fiber volume.

Resin dominated properties like shear, compression and transverse tension are affected by the void content, resin content and fiber volume. For every one percent increase in the void content, resin dominated properties generally decrease in the range of 5 to 10 percent. Hence, to get any meaningful test data fiber volume resin content and void content should be representative of the part for which design allowables or acceptance testing is being done.

Fiber dominated mechanical properties should always be normalized to the design fiber volume. Resin dominated properties cannot be normalized and should be rerun in case the fiber volume, resin content and void content of the specimens taken from the panel are outside the design limits.

Testing for glass transition temperature (Tg) should be done to determine the extent of the cure and detect any minute changes in resin formulation. Recommended test method for glass transition temperature is Dynamic Mechanical Analysis (DMA) which gives a plot of real and complex shear moduli versus temperature. Table I lists the various physical properties and the test methods used for determining them. Reference 12 gives the alternate test method for determining fiber volume for Kevlar composites. To get accurate data, extreme care should be taken to make sure that only the resin and not the fiber is digested by the solvent.

TENSION TESTING

The various tension test methods for composites are summarized in Table II. This table describes the available test methods, type of specimens needed and the test setup. It gives advantages and disadvantages of various methods with the recommendation if the test data are good for use in design or only for quality control.

Recommended test method for getting design allowables for tensile strength and modulus is ASTM D-3039. Alignment of the specimen is very critical and the test fixture shown in Fig. 1 is recommended. This method can be used for testing coupon specimens in direction 1, 2 and crossply layups. In testing of neat resins or direction 2 for composites, end tabs are not necessary. Direction 2 tension testing for composites can also be done using 90 deg hoop wound tube specimens in the test fixture shown in Fig. 2 (Ref. 13). Generally data obtained from hoop wound tubes are higher than those obtained from coupons because of minimal edge effects and also lower void content (better compaction in tubes). Alignment of the specimen is very critical.

For tension testing of direction 3 (through thickness) specimens, the test fixture shown in Fig. 3 is recommended. Here the bond strength between the composite and steel disc should be greater than the direction 3 tensile strength (interlaminar tension) of the composite. Kevlar and glass composites which generally have relatively low interlaminar tensile strength (direction 3 tensile strength) do not give any problem. For graphite composites which have relatively high value of 3 direction tension, selection of the appropriate bonding adhesive is important to make sure the failure occurs in the composite and not at the composite and steel interface.

*Kevlar is a registered trademark of DuPont for aramid fiber.

Tensile strength and modulus values can also be determined using ring specimens. Rings are more representative of the cylindrical filament wound part and give more representative specimens than the coupons. It was found in Reference 1, 2 that after normalizing for fiber volume, data obtained were equivalent for rings and coupons. Absolute values for the rings were slightly higher because of the higher fiber volume for the rings as compared to that for the coupons, probably because of higher winding tension for the rings. With this in view, coupon testing is recommended as the ring testing is time consuming and costly. Test setup for hydrostatic testing of rings is shown in Fig. 4.

NOL ring split disk method gives the apparent rather than the true tensile strength because of the bending moment imposed during the test. Test data obtained from this method are recommended only for material evaluation and quality control. These data are not recommended for design purposes.

Elongated ring split disk (shown in Fig. 5) minimizes bending stresses during the test, but the fiber and void volume may not be uniform in the specimen due to difference in winding tension between the ring section and the straight section. This method is also recommended only for material evaluation and comparative quality control and not for determining design allowables.

Testing the 5.75-in. pressure vessel to determine hoop fiber stress is good for material evaluation, screening and quality control acceptance testing. This bottle is not recommended for dome contour, dome reinforcement or attachment studies because of too small a size. Data obtained from this testing are the maximum possible available for the full-scale design. Hoop fiber stress obtained depends upon the stress ratio, layup and processing. Air Force Rocket Propulsion Laboratory (AFRPL) is working in the direction of developing a Standard Test Evaluation Bottle (STEB) for the industry. Tentative diameter for this bottle is 10 inches. This bottle is currently being evaluated by the industry to check if it can be used to get the design information not available from the present 5.75-in. bottle (ASTM D-2585).

Various modifications to the ASTM 5.75-in. pressure vessel are possible. The factors which affect the pressure vessel performance include the stress ratio, dome contour, dome reinforcements, composite layup, processing and size (diameter). Besides the material system, the single most important parameter which affects the pressure vessel performance is the processing.

COMPRESSION TESTING

Compressive strength data obtained for a particular material system depends upon the mode of failure. If the failure is not truly compressive, low value for the test data is obtained. In general, specimens giving high strength data fail in the fiber compression mode. The specimens failing either by flexure or delamination generally give medium strength data. The specimens which give low strength data generally fail by Euler buckling with large unsupported specimen length. If the specimen is designed so as not to fail by buckling, compressive strength values obtained by the fiber compressive failure mode is the upper bound limit. The strengths predicted by either the flexure or the delamination failure modes give the lower bound values. Comparison of the experimental and predicted compressive strengths for T-300/5208 material system for the three failure modes is shown in Fig. 6, Ref. 6. The values of compressive modulus is generally not dependent on the test method (2, 3, 7).

In ASTM D-695 and FTMS-406 compression test methods, the specimens are end loaded and compressive strength data obtained are on the low side due to improper failure modes including end brooming. Load transfer is not through shear and is very inefficient. Though the dog bone shape in ASTM D-695 helps to transfer the load to the center, machining problems generally result in stress concentration at the corners leading to low compressive strength. Basically both the ASTM D-695 and FTMS-406 used as such are suitable for neat resins or plastics rather than the fiber reinforced composites.

Modifications to the above test methods for use with composites include the use of the end caps and/or end tabs. Setup used by SoRI (Southern Research Institute) using a dog bone specimen with end cap modification is shown in Fig. 7. Morton Thiokol, Inc. modification (Fig. 8) of ASTM D-695 uses rectangular coupons with the end caps. These modifications give more efficient load transfer through shear. Though not the ideal test methods for getting design data, they are fast and adequate for quality control, material evaluation and product acceptance purposes. Specimen thickness can be varied with the proper fixture design.

An end caps test fixture (Fig. 9) used by Irion and Adams of the University of Wyoming (Ref. 5) gives relatively higher test data due to effective load transfer. As reported by the above authors, data obtained by this test fixture are comparable to those obtained from ASTM D-3410 type test methods where load transfer is very effective.

For compression testing of cylinders, modification to ASTM D-695 includes use of bonded end plugs to prevent end brooming. Upper surfaces of the cylindrical surfaces should be parallel to within 0.001 in. to get proper alignment and reliable data. This method is recommended for material evaluation and quality control only. The test setup is shown in Fig. 10. Hydrostatic compression test method using ASTM D-2586 is also good only for material evaluation and comparative quality control. Ring testing by compression (Fig. 11) is also recommended only for quality control material acceptance. It gives failure load, stiffness and deflection at failure. Test setup for testing direction 3 compressive strength is similar to that used for direction 3 tension and is shown in Fig. 3.

ASTM D-3410 (Celanese developed) test method gives high compressive strength numbers due to very effective load transfer through shear. It uses a conical type fixture. This method has specimen thickness limitations but gives test data comparable to those obtained from the sandwich beam test method. This method is very highly recommended for getting design allowables. The test setup is shown in Fig. 12. IITRI (Illinois Institute of Technology Research Institute) modification of ASTM D-3410 includes the use of a pyramidal wedge type fixture instead of the conical type in ASTM D-3410. Use of pyramidal wedges allows specimens of various thicknesses. It gives data similar to those obtained with D-3410 and is also highly recommended for the design allowables. The test setup is shown in Fig. 13.

Modification used by SoRI to ASTM D-3410 includes test fixtures shown in Fig. 14 and Fig. 15. The modification in Fig. 14 does not have end tabs and is not supported throughout the specimen length. This gives lower data and this method is not recommended for design but only for quality control comparative purposes. The modification in Fig. 15 uses end tabs and the specimen is supported through the specimen length. This method gives relatively higher test data and is recommended. Test data using the above two modifications are shown in Fig. 16. As reported in Ref. 2, test data for configuration 1 (Fig. 15) are higher than those for configuration 2 (Fig. 14) for the various material systems.

Another type of compression test fixture which was developed by the National Bureau of Standards (Ref. 14, 15) is shown in Fig. 17. This fixture combines certain features of the IITRI and Celanese test fixtures, while introducing a feature which allows tensile loading. The test setup consists of a test specimen contained in end fixtures which are constrained to move in a colinear fashion by rigid rods and an external housing. Specimen gripping is achieved by friction due to interference between end fixtures and cylindrical specimen buildup. This method utilizes both square cross section and round cross section specimens. The round cross section is recommended for 0 deg unidirectional composites only.

Load transfer in the Sandwich Beam test method is the most effective (3, 16, 17). Test data obtained by this method give compressive strength numbers which match or are higher (Ref. 3) than those obtained by ASTM D-3410 of both Celanese and IITRI designs. Where practical, this test method should be run. This is highly recommended for getting design allowables. Disadvantages of the sandwich beam test method include high cost and its general unsuitability for running environmental aging tests.

SHEAR TESTING

Shear testing consists of testing for interlaminar and inplane shear. Various test methods for testing of interlaminar and inplane shear for composites are outlined in Table IV.

Interlaminar Shear Testing

In interlaminar shear testing, short beam shear (SBS) using the specimens cut from the NOL ring or flat panels are tested as per ASTM D-2344. SBS is dependent upon the void content and generally NOL ring specimens give higher SBS strength (Ref. 1, 10) due to low void content and better fiber/resin interface bonding. This test is recommended only for material evaluation and quality control. It is not recommended for design allowables because of nonuniform stress distribution in the test specimens.

Iosipescu (double V-notch) shear specimen (Fig. 18) consists of a flat laminated composite coupon with symmetric V-notches (Ref. 8, 18) along the two free edges. The ends of the coupon are gripped by fixtures (bolted, bonded or clamped) and the load is introduced through tension or compression. This is a simple test and the data obtained can be used either for material evaluation, quality control or design.

Data from double notch shear(ASTM D-3846) are not recommended either for design or for quality control. The data are generally in error (Ref. 10) as these are dependent upon the notch depth which is difficult to control.

Testing for interlaminar tension is done as per the test fixture shown in Fig. 3. These data are good only if the interlaminar shear strength of the composite is lower than the bond strength of the composite to the steel disk. For glass and Kevlar composites, generally no problem arises as shear strength is on the low side, but for graphite composites, which have relatively high interlaminar strength, care should be taken in selecting the appropriate adhesive to make sure the failure occurs in the composite and not at the composite/steel interface.

Inplane Shear Testing

Tube torsion using 0 or 90 deg winding gives the most accurate inplane shear strength and modulus data (1, 2, 9, 10) and is highly recommended for design. Similar data can also be obtained using solid rod torsion. Coupon torsion also gives very accurate shear strength and modulus data which can be used for the design. Coupon torsion can also be used to determine shear modulus in other planes including G_{13}, G_{23} (Ref 1, 2) and is highly recommended.

Panel shear (picture frame) and plate twist testing described in Ref. 2, 9 give test data acceptable for material evaluation and design.

Ten degree tensile shear testing developed by NASA to determine shear strength and modulus is not recommended. It gives low shear strength and high shear modulus (Ref. 10) due to tensile shear coupling.

± 45 deg tensile shear testing is a standard ASTM test method designated ASTM D-3518 and gives minimal tensile-shear coupling (Ref. 1, 10). This test method is fast, needs no tab bonding, gives acceptable data and is highly recommended for determining the composite shear strength and the modulus.

Iosipescu shear test as described above (Fig. 18) gives excellent data for inplane shear and is recommended both for the material evaluation and design allowables.

Rail shear testing is used widely for determining composite shear strength. This test has been used for a variety of materials and laminate configurations at room and elevated temperatures. A number of variations (2 rail shear, 3 rail shear) of the rail shear specimen have been used. Tensile or compressive loads are introduced at the rail ends to displace them essentially parallel to one another. Testing setup for rail shear is shown in Fig. 19.

In four-point ring twist testing (Fig. 20, Ref. 19), the specimen is subjected to out of plane four point loading. Applied are four forces of equal magnitude, two upwards at 0 and 180 deg and two downward at 90 and 270 degree. This method is used to measure the shear moduli of isotropic and composite materials. This test is simple and fast with no requirement for elaborate instrumentation or setup. Using this method, accurate values of the shear moduli can be measured at room temperature, cryogenic temperature and elevated temperatures.

Double notch shear as described above gives unreliable test data due to problems with the notch depth and for that reason is not recommended either for design allowables or for quality control.

The crossbeam shear specimen (Fig. 21, Ref. 8) consists of a compressive top flange separated from the bottom flange by a honeycomb core. When the orthogonal legs of the beam are loaded in positive and negative bending, a state of equal magnitude tension and compression is produced in the top flange test section (neglecting core influence and stress concentrations). This test is not recommended either for design or quality control as the specimen is complicated to fabricate and requires a large amount of the material.

A variety of slotted coupon specimens has been used to obtain shear properties of metals and composites (Fig. 22, Ref. 8). Slotted coupon has the advantage of requiring little in the way of material, fabrication time, fixtures and test apparatus. However the specimen is typically characterized by undesirable normal stresses and high stress concentrations at the slot ends which lead to early failures, outside the test section, giving low values of shear strength.

Data for interlaminar and inplane shear strength as determined by various test methods for epoxy material system using Kevlar, glass and graphite fiber are shown in Fig. 23.

SUMMARY AND RECOMMENDATIONS

Sample preparation and test methods for composites are not fully developed or standardized for the industry. The test data depend upon the test method, specimen design and the composite void content. In order to obtain the most meaningful data, specimen design and fabrication should

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13. R. E. Allred, H. K. Street, R. J. Martinez, "Improvement of Transverse Composite Strength Test Specimen and Materials Development," 24th National SAMPE Symposium, May 1979, p. 31.

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15. J. M. Whitney, I. M. Daniel, R. B. Pipes, "Experimental Mechanics of Fiber Reinforced Composite Materials," The Society For Experimental Stress Analysis, Brookfield Center, Connecticut, 06805, 1982, p. 179.

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18. D. E. Walrath and D. F. Adams, "The Iosipescu Shear Test as Applied to Composite Materials," Experimental Mechanics, March 1983, p. 105-110.

19. L. B. Greszczuk, "Applications of Four-Point Ring-Twist Test for Determining Shear Modulus of Filamentary Composites." Test Methods and Design Allowables for Fibrous Composites ASTM STP-734, p. 21-33.

TABLE 1

PHYSICAL PROPERTY TESTING OF COMPOSITES

Property Evaluated	Test Method	Comments
Density	ASTM D-792	Liquid displacement
Fiber Volume	ASTM D-2584	Resin burn off for glass
Resin Content	ASTM D-3171	Solvent digestion for Kevlar and graphite
Void Content	ASTM D-2734	Void content calculation
Glass Transition Temperature (Tg)	Heat Distortion Temperature (ASTM D-648)	Gives softening temperature, Tg
	Thermal Mechanical Analysis (TMA)	Gives coefficient of thermal expansions, Tg
	Differential Scanning Calorimetry (DSC)	Gives extent of cure, Tg
	Dynamic Mechanical Analysis (DMA)	Gives Tg. Minute changes in resin formulation can be detected

TABLE 2

TENSION TESTING OF COMPOSITES

Test Method	Specimen Type	Test Set-up	Comments
ASTM D-638	Dog Bone Coupon	ASTM D-638	Test good only for neat resins. Machining and load transfer problems for fiber reinforced composite specimens.
ASTM D-3039	Coupon	Figure 1	Industry standard for composites. No end tabs needed for transverse tension and neat resin specimens. Recommended for design allowables.
ASTM D-3039 (Mod)	Tubes	Figure 2	Need grips for tubes. Especially good for direction 2 or cross ply testing. Minimizes edge effects encountered in coupon specimens. Recommended for design.
MTI/SoRI	Disk	Figure 3	3-direction tensile strength (tensile adhesion). Method good only for composites where bond strength of the composite and the steel disk is greater than direction 3 tensile strength.
Hydrostatic Ring SoRI/MTI	Ring/Cylinder	Figure 4	Costs more but gives data comparable to that obtained with coupons. Not recommended for routine testing.
ASTM D-2290	NOL Ring Split Disk	ASTM D-2290	Gives apparent rather than the true tensile strength. Bending moment imposed during the test. Data good only for material evaluation in Quality Control. Not good for design.
ASTM D-2290 (Mod)	Elongated Ring Split Disk	Figure 5	Minimizes bending stresses during testing. Fiber and void content in the specimen may be nonuniform due to difference in winding tension between the ring section and the straight section. Good for Quality Control.
ASTM D-2585	5.75-In. Pressure Vessels	ASTM D-2585	Biaxial tension. Method good for Material Evaluation and screening. Not recommended for dome contour, reinforcement or attachment studies.
ASTM D-2585 (Mod)	Larger Pressure Vessels at Different Designs		Can give design information including dome contour, dome reinforcements, wind angle, process variables, etc.

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TABLE 3

COMPRESSION TESTING OF COMPOSITES

Test Method	Specimen Type	Test Set-up	Comments
ASTM D-695	Dog Bone Coupon	ASTM D-695	Specimen end loading. End Brooming - Improper failure modes. Gives low strength due to inefficient load transfer. Probable stress concentraton in dog bone machining. Good for plastics (neat resins). Not good for composites. Not recommended for design allowables.
FTMS-406	Rectangular Coupon	FTMS-406	Same as above. Gives low strengths due to inefficient load transfer. Good for plastics (neat resins) not for fibrous composites.
ASTM D-695 End Cap.(Mod) SoRI	Dog Bone Coupon	Figure 7	Efficient load transfer. Gives higher strength. Probable stress concentration in dog bone specimen machining. Specimen thickness can be varied with proper fixture design. Good for Quality Control material acceptance, not for design allowables.
ASTM D-695 End Cap, (Mod) MTI	Rectangular Coupon	Figure 8	Efficient load transfer. Gives high strength numbers. Specimen width constant, thickness can be varied. Good for Quality Control, comparative purposes, not for design allowables.
ASTM D-695 (Mod) End Cap, Univ of Wy	Coupon	Figure 9	Gives relatively higher data due to effective load transfer. Data obtained comparable to ASTM D-3410 type test methods. Can be used for quality control and design allowables.
ASTM D-695 (Mod) End Plug, MTI	Cylinder	Figure 10	End plugs for effective load transfer and to prevent improper failure modes at the specimen ends.
ASTM D-2586	Cylinder	ASTM D-2586	Hydrostatic compression, good for material evaluation, comparative quality control.
ASTM D-695 MTI (Mod)	Ring	Figure 11	For quality control material acceptance. Comparison of different materials. Gives failure load, stiffness and deflection at failure.
ASTM D-695 MTI/SoRI (Mod)	Disc	Figure 3	Similar to test fixture used for 3 direction tension. Minimizes end brooming.
ASTM D-3410 (Celanese)	Coupon	Figure 12	Very effective load transfer. Gives compressive strength numbers comparable to sandwich beam. Uses conical type fixture. Very highly recommended for getting design allowables.
ASTM D-3410 IITRI (Mod)	Coupon	Figure 13	Same as above except for modification that it uses pyramidal, wedge type fixtures. Highly recommended for design allowables.
ASTM D-3410 SoRI (Mod)	Coupon	Figure 14	Modification of D-3410. Uses bearing to support the specimens. Specimen does not have end tabs and is not supported throughout the length. Gives lower data. Good for acceptance testing. Not recommended for design allowables.
ASTM D-3410 SoRI (Mod)	Coupon	Figure 15	Modification of D-3410. Specimen bonded with end tabs and is supported throughout the length. Gives higher strength data. Recommended for design.
ASTM D-3410 NBS (Mod)	Coupon or Cylindrical	Figure 17 Ref 14, 15	Modification of ASTM D-3410. Combines features of Celanese and IITRI designs. This test fixture also allows tensile loading. Recommended for both design and material evaluation.
Sandwich Beam	Coupon	4 pt Flexure Ref 3, 16, 17 ASTM C364-61	Very effective load transfer. If test properly conducted, gives ideal compressive strength numbers. Data equal or slightly higher than that obtained from ASTM D-3410 test method. Highly recommended for design allowables.

TABLE 4

INTERLAMINAR AND INPLANE SHEAR TESTING OF COMPOSITES

Test Type	Test Method	Specimen Type	Data Obtained Strength	Data Obtained Modulus	Test Setup	Comments
Interlaminar Shear						
Short Beam Shear (SBS)	ASTM D-2344	Panel/NOL Ring	Yes	No	ASTM D-2344	Nonuniform stress distribution. Test data not good for design. Used only for comparison and quality control.
Double Notch Shear	ASTM D-3846	Coupon	Yes	No	ASTM D-3846	Notch depth critical. Data not reliable. Not recommended for design or quality control.
Iosipescu (Double V Notch)	Ref 8, 18	Coupon	Yes	Yes	Figure 18	Gives excellent data. Good for design.
Tensile Adhesion (Interlaminar Tension)	MTI/SoRI	Disk	Yes	No	Figure 3	Composite interlaminar shear should be less than bond strength of composite with steel disk.
Inplane Shear						
Tube Torsion (0,90 deg)	Torsion	Hollow Tube	Yes	Yes	—	Gives most accurate values of G_{12}, t_{12}. Recommended for design.
Rod Torsion	Torsion	Solid Rod	Yes	Yes	—	Same as above
Coupon Torsion	Torsion	Coupon	Yes	Yes	—	Same as above. Can also be used to determine G_{13} and G_{23}.
Panel Shear (Picture Frame)	Ref 2, 9	Coupon	No	Yes		Induces stress concentration at the specimen edges. Questionable shear strength data.
Plate Twist	Ref 2, 9	Coupon	No	Yes		Gives good modulus data.
10 Deg Tensile Shear	NASA-TN-D-8215	Coupon	Yes	Yes	ASTM D-3039	Gives low strength and high modulus due to tensile shear coupling. Not recommended for design.
±45 Deg Tensile Testing	ASTM D-3518 ASTM D-3518	Coupon Tube	Yes Yes	Yes Yes	ASTM D-3518	Minimal shear coupling. Gives acceptable data. Can be used for design allowables. Avoid edge effects.
Iosipescu	Ref 8, 18	Coupon	Yes	Yes	Figure 18	Gives excellent data. Can be used for design allowables.
Rail Shear	Ref 8, 15	Coupon	Yes	No	Figure 19	Gives good strength data if no stress concentration at the edges.
4 Point Ring Twist	Ref 19	Ring	No	Yes	Figure 20	Gives good data for modulus . all temperatures.
Double Notch Shear	ASTM D-3846	Coupon	Yes	No	ASTM D-3846	Gives unreliable data. Notch depth critical. Not recommended for design.
Cross Sandwich Beam Shear	Ref 8	Beam	Yes	No	Figure 21	Induces stress concentration within the test section and at the corners. Specimen complicated to fabricate and requires large amount of material. Not recommended.
Slotted Tension Shear	Ref 8	Coupon	Yes	No	Figure 22	Stress concentration gives low values of stress. Not recommended for design.

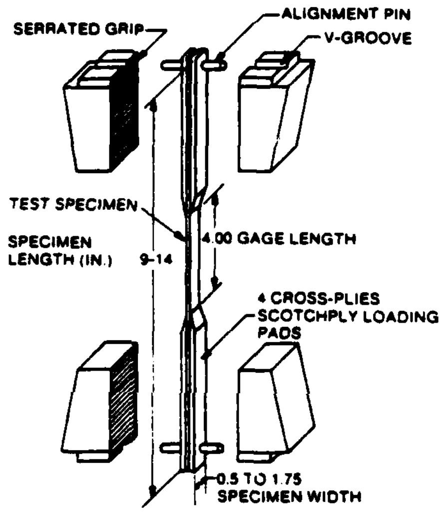

Figure 1. Alignment Test Fixture for Tension Testing (ASTM D-3039)

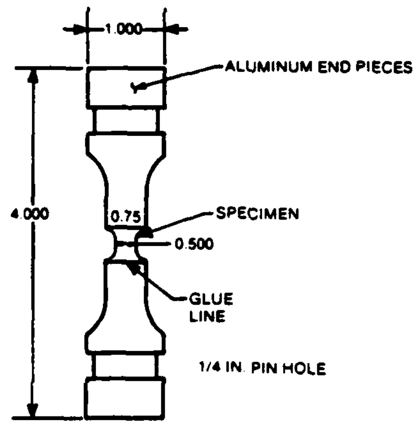

Figure 3b. SoRI Direction 3 Test Fixture

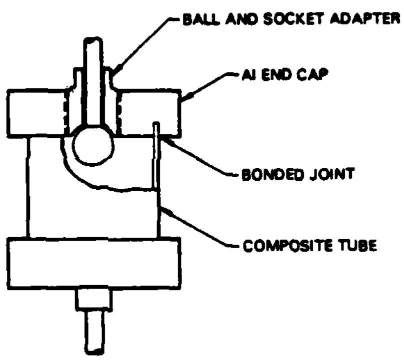

Figure 2. Transverse Tension Testing for Composite Tubes

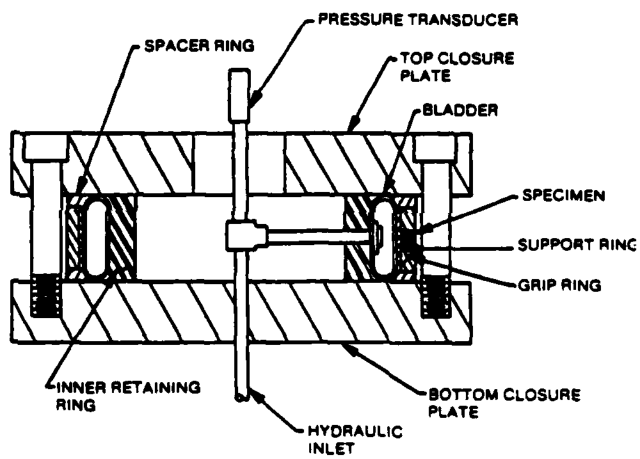

Figure 4. Hydrostatic Set-up For Tension Testing of Ring Specimens

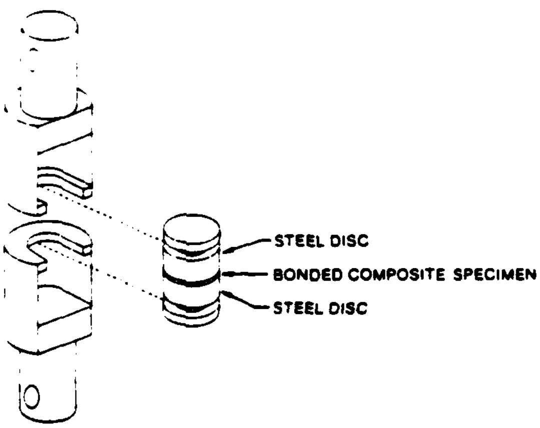

Figure 3a. Morton Thiokol Direction 3 Tension Testing Fixture

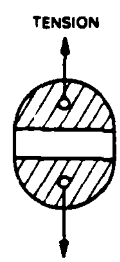

Figure 5. Elongated Ring Split Disk Testing

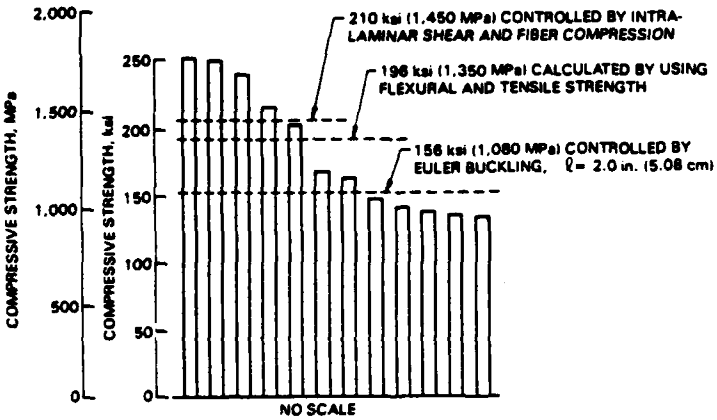

Figure 6. Experimental and Predicted Compressive Strength of T300/5208 for Different Failure Modes

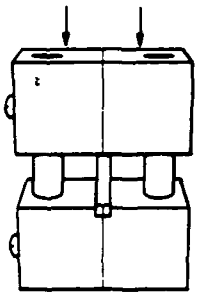

Figure 9. End Load Compressio Fixture with Specimen

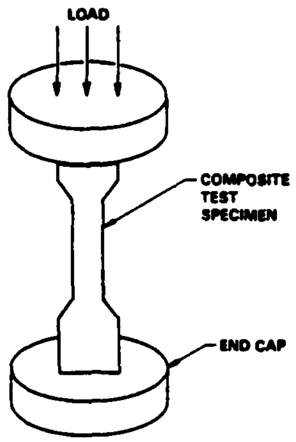

Figure 7. SoRI Compression End Cap Test Fixture

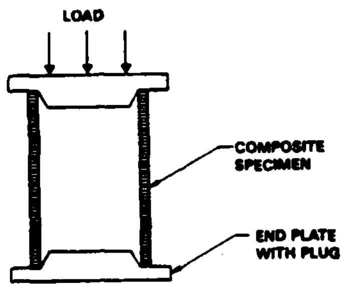

Figure 10. Compression Test Set-up for Cylinders

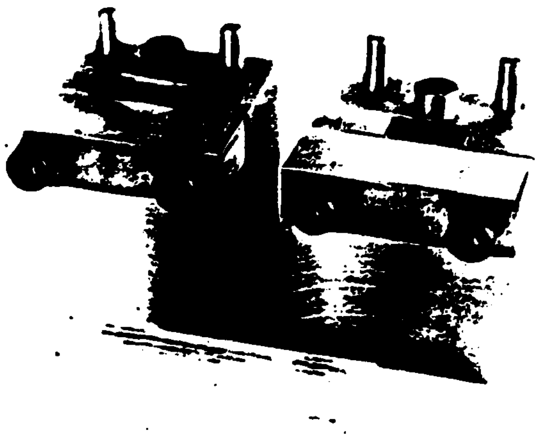

Figure 8. End Cap Test Fixture with Specimen

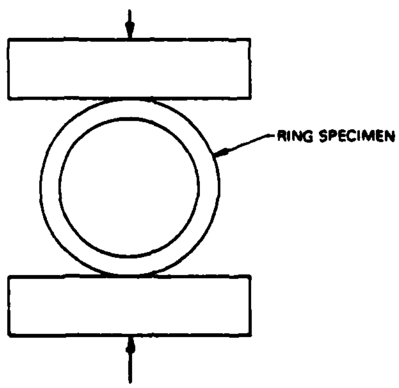

Figure 11. Compression Testing of Ring Specimens

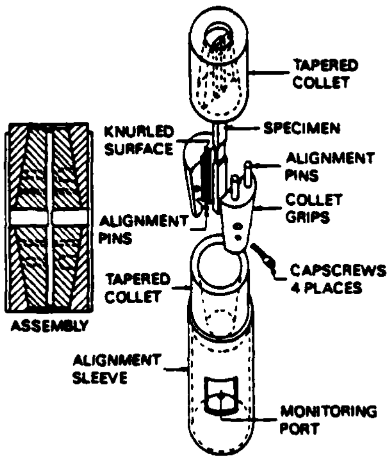

Figure 12. ASTM D-3410(Celanese) Compression Test Fixture Using Conical Wedges

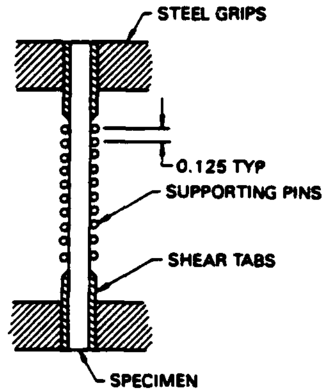

Figure 15. Compression Test Fixture-Loading Configuration 1

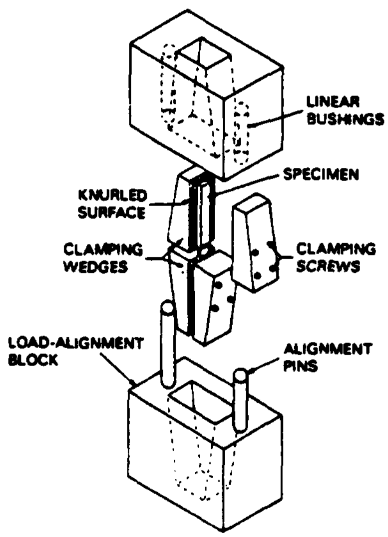

Figure 13. IITRI Compression Test Fixture Using Pyramidal Wedges

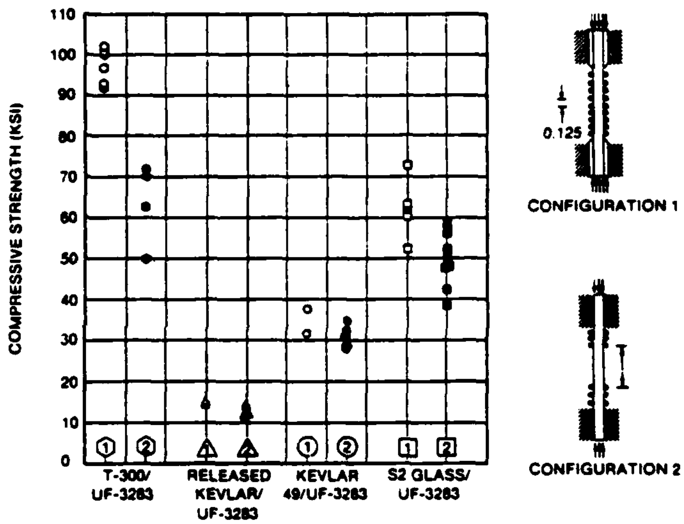

Figure 16. Compressive Strength Vs Specimen Free Length

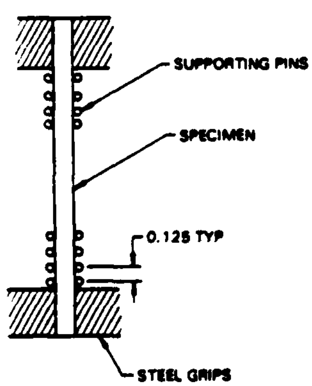

Figure 14. Compression Test Fixture-Loading Configuration 2

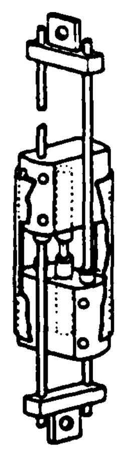

Figure 17. NBS Compression Test Fixture

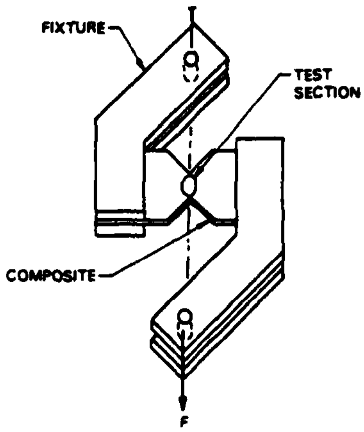

Figure 18. Double V-Notched (Iosipescu) Shear Testing

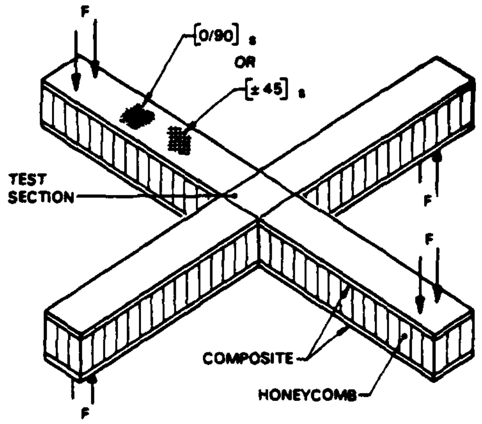

Figure 21. Cross-Beam Sandwich Testing

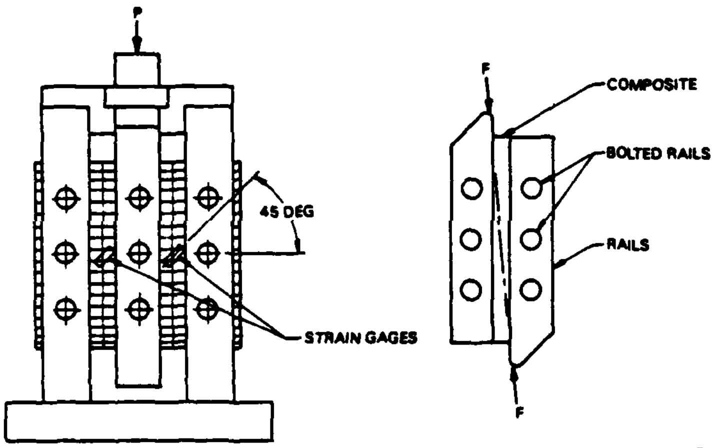

Figure 19. Rail Shear Testing

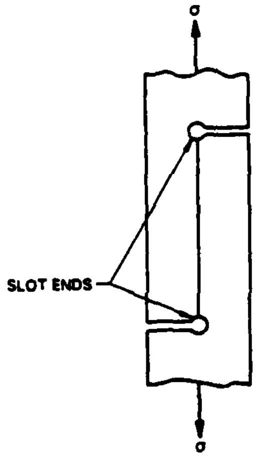

Figure 22. Slotted Coupon Testing

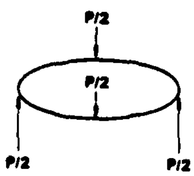

Figure 20. Four Point Loading of Ring Specimen

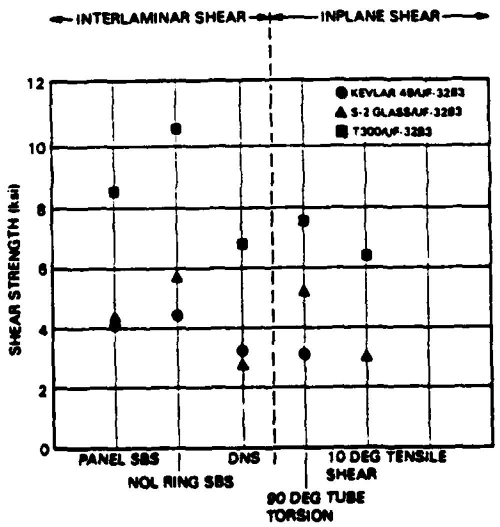

Figure 23. Shear Strength as Determined by Various Test Methods

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